SOIL FERTILITY AND FERTILIZERS.

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By

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PREFACE.

This book has been written to be within reach of the student, farmer, manufacturer and other persons interested in the subject of "Fertilizers." Technical terms have been omitted as much as possible.

It has been the aim of the writer to bring this subject up to date, not only from the manufacturers viewpoint but from the actual field results as well. A full discussion of the data in the tables has necessarily been avoided so as not to make the book too voluminous.

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J. E. HALLIGAN.

Baton Rouge, La.

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CHAPTER I.

CHEMICAL ELEMENTS NEEDED BY PLANTS AND THE COMPOSITION OF PLANTS.

In order to thoroughly understand the subject "fertilizers," we must become familiar with the chemical elements needed by plants.

There are about 81 chemical elements known to us, but only 15 of these are required for plant life so far as we know.

The Fifteen Elements.—Hydrogen, oxygen, nitrogen, potassium, phosphorus, calcium, sulphur, silicon, iron, chlorine, magnesium, sodium, aluminum and manganese are the elements used by plants. Hydrogen, oxygen, nitrogen and chlorine, in the pure state, generally occur as gases, while the other elements are solids.

The Symbols.—The chemist uses the following symbols for these elements.

Hydrogen (H)	Oxygen (O)	Nitrogen (N)
Carbon (C)	Potassium (K)	Phosphorus (P)
Calcium (Ca)	Sulphur (S)	Silicon (Si)
Iron (Fe)	Chlorine (Cl)	Magnesium (Mg)
Sodium (Na)	Aluminum (Al)	Manganese (Mn)

Small amounts of oxygen are sometimes used by plants in the elementary state. Certain plants also use nitrogen in the free state. All other elements, and generally oxygen and nitrogen must be combined with other of these elements to be favorable for the support of plant life.

Hydrogen.—This is a colorless invisible gas, having no smell or taste. It is generally found in combination with other elements as water, hydrochloric acid, marsh gas, sulphuretted hydrogen, all acids and most organic (animal and vegetable) compounds. It is most commonly found as water (H_2O), which is the most necessary food of the plant. In the free state hydrogen occurs only in small quantities upon the earth in the gases of petroleum wells, around volcanic eruptions, and it is evolved by the fermentation and decomposition of some organic substances.

Oxygen.—In the free gaseous state, about one-fifth, by bulk, of the atmosphere is made up of this element, mechanically mixed with nitrogen. It is found in enormous quantities in combination with other elements. It constitutes about eight-ninths by weight of water and nearly one-half of the earth's crust. All combustion and decay require oxygen. The plant stores up oxygen in combination with other elements and without oxygen plants would die. The plant takes in oxygen, from the atmosphere, in combination with carbon, as carbonic acid gas, through the openings on the under sides of the leaves; the carbon is absorbed and the excess of oxygen given off. Oxygen combines with most other elements forming oxides. It often combines with other elements in varied amounts forming oxides of different composition which are generally quite stable. The color of soils is often determined by oxides such as iron oxides. The iron oxides influence the moisture condition of soils because of their absorptive qualities and help to oxidize organic substances in the soil. The roots of plants when deprived of air in the soil are able to draw upon iron oxides for oxygen.

Nitrogen.—About four-fifths of the atmosphere, or about 35,000 tons over every acre of land, is made up of nitrogen in the free gaseous state. In combination this element is found in many substances such as ammonia, sodium nitrate (Chile saltpeter), potassium nitrate and many organic compounds. Certain plants, namely the legumes, of which the pea, bean, alfalfa, clovers, cowpea, soy bean, etc. are members, have the power of gathering nitrogen from the air, by means of certain growths (tubercles) on their roots. Stone[1] of the Massachusetts Agricultural College says in part: "There is evidence to show that a large number of organisms have the power of fixing nitrogen in the soil, for example, besides the species of clover bacteria, there is evidence to show that many of the algae which live in the soil and certain molds will do the same thing. In our work here, we find the largest percentage of nitrogen in those solutions which are contaminated with the blue bread mold (Pencillium) showing that it is a nitrogen fixer. I think it will be

shown later on that quite a little nitrogen is fixed in the soil by this type of organism, exclusive of those on the nodules of the legumes." As far as we know our other plants are not capable of obtaining nitrogen in the free state. Although nitrogen is abundant in the free state it cannot be used as such by most plants and it must be combined with other elements to be available as plant food. Nitrogen as sold in fertilizers is in combination with other elements, and is the most fugitive and expensive of the essential elements. This will be described more fully later on.

Carbon.—This element is found in the free state in charcoal, graphite and diamonds. In coal it is also present in an impure state. Muck and peat contain considerable carbon. Humus (the decayed organic matter in soils) is made up partly of carbon. In combination with oxygen we find carbon as carbon dioxide (carbonic acid gas) in the air. It is present in greater quantities in plant life than any other element. Henry[2] says: "10,000 volumes of air contain about 3 volumes of carbonic acid gas; 32 cubic yards of air hold one pound of this gas. An acre of growing wheat will gather during four months, 2,000 pounds of carbonic acid gas, or an amount equal to all the air contains over the same area of land to a height of three miles." All of our farm crops use a great amount of carbon in the form of carbonic acid gas. All carbonates (limestone, chalk, marble, shells, etc.) and all organic substances contain carbon. The carbonates of lime found in the soil exert a great influence upon the conversion of some forms of nitrogen into available plant food and in the general physical condition of the soil.

Potassium in combination is very common. It is mined in large quantities as potassium salts in the Stassfurt mines of Germany. The presence of this element in wood ashes, as potassium carbonate, makes this substance a valuable fertilizer. Potassium is found in most rocks and soils. In plants it is associated with organic acids. It is found in sea-water and saltpeter. This element is essential to plant growth and is found in the stems, leaves and fruits of plants.

Phosphorus is found in combination with oxygen and metals, as phosphates. Vast deposits of phosphates are found in Tennessee, South Carolina, Florida and some of the western states. It is present in many rocks and most soils and is an important element for plant food. It exists in combination with organic substances in plants and constitutes an important part of the ash of plants. Bones, which contain about 60-65 per cent. of calcium phosphate, are an important source of phosphorus for plant food.

Calcium is an element which occurs in combination in many substances as lime, marble, shells, coral and gypsum. It makes up about one-sixteenth part of the earth's crust. Plants and animals require this element, sometimes in larger amounts than one would imagine. The bones of animals are made up largely of this element in combination as lime. Lime is a great factor in regulating the physical condition of soils.

Sulphur.—This is a yellow substance which is found in the free state in large deposits in Louisiana, western United States, and Sicily. It is found in combination in gypsum (an important indirect fertilizer), pyrites (a source of sulphuric acid), galena, etc. It is also found in many natural waters. In plants it occupies an important place, occurring in organic compounds as protein, or nitrogenous portions, and also as sulphuric acid. Most of our soils are sufficiently supplied with this element for the nourishment of plants.

Silicon occurs in combination as sand, flint, quartz, etc., and constitutes about one-half the earth's crust. It is present in most rocks and soils and plays an important part in the physical make up of the soil. Plants require this element to support certain parts of their structure. The hulls and straws of plant substances are often comparatively rich in this element.

Iron is a very common element and in combination it is widely distributed. Although used in small amounts by plants it is nevertheless very important, as it is necessary for the production and activity of chlorophyll (the green coloring matter of

plants). The color of soils (red and yellow) are chiefly due to the presence of iron compounds.

Chlorine is most commonly found as chloride (common salt). It also occurs in combination with hydrogen, as hydrochloric acid.

Magnesium.—This element is found in most rocks and soils in sufficient amounts for the needs of the plant. It is used in different parts of the plant but mainly in the formation of seeds.

Sodium.—Chloride is the commonest compound of this element and is present in common salt, sea-water, salt lakes, and in many springs and waters. It occurs in sodium carbonate and sodium nitrate; the latter compound is a valuable fertilizer because of its nitrogen content. Sodium is believed to be helpful in plant growth.

Aluminum.—This element is the most widely distributed next to oxygen and silicon of the earth's crust. About one-twelfth of the earth's crust is aluminum. In combination it is found in clay, slate, kaolin, etc. Although it is very abundant it is not used much by plants.

Manganese occurs in combination as manganese blend, manganese spar, manganite, etc. Plants use this element in small amounts although it is not believed to be necessary for plant growth.

Distribution of the Elements.—Clarke[3] of the United States Geological survey has estimated the relative proportions of the common elements making up the earth's crust to a depth of ten miles from the surface. He estimates that:

93 per cent. is composed of solid rock, etc.

7 per cent. is composed of water and air.

The air amounts to about 0.03 per cent.

The following give the distribution by weight of the elements mentioned.

Element	Solid crust 93 per cent.	Ocean 7 per cent.	Mean including air
1. Oxygen	47.29	85.79	49.98
2. Silicon	27.21	——	25.30
3. Aluminum	7.81	——	7.26
4. Iron	5.46	——	5.08
5. Calcium	3.77	0.05	3.51
6. Magnesium	2.68	0.14	2.50
7. Sodium	2.36	1.14	2.28
8. Potassium	2.40	0.04	2.23
9. Hydrogen	0.21	10.67	0.94
10. Titanium	0.33	——	0.30
11. Carbon	0.22	0.002	0.21
12. Chlorine	0.01	2.07	0.15
13. Phosphorus	0.10	——	0.09
14. Manganese	0.08	——	0.07
15. Sulphur	0.03	0.09	0.04
16. Barium	0.03	——	0.03
17. Nitrogen	——	——	0.02
18. Fluorine	0.02	——	0.02
19. Chromium	0.01	——	0.01

The above figures are not claimed to be absolutely correct but have been estimated from analyses of rocks and serve to give us an approximate idea of the distribution of the above named elements.

Composition of Air.—The composition of air[1] at different heights, if each element was separate from the others would be:

Altitude in kilometers	Carbon dioxide	Oxygen	Argon	Nitrogen	Hydrogen
0	0.03	21.00	1.20	77.75	0.02
10 (= 6.214 miles)	0.02	18.43	0.75	80.74	0.06
20	0.01	16.07	0.46	83.26	0.20
30	0.00	13.90	0.28	85.18	0.64
40	——	11.86	0.16	85.94	2.04
50	——	9.83	0.12	83.94	6.11
60	——	7.52	0.00	75.54	16.94
70	——	4.70	——	56.20	39.10
80	——	2.20	——	31.00	66.80
90	——	0.70	——	12.90	86.40
100 (= 62.14 miles)	——	0.30	——	4.60	95.10

The carbon dioxide and oxygen decrease in amounts as the height increases. The carbon dioxide is not found at the height

of 30 kilometers (18.6 miles). Nitrogen is greatest at 25 miles and diminishes as the height increases from that point. Hydrogen increases with the height.

Much of the remaining portion of this chapter has been adapted from Halligan's "Elementary Treatise on Stock Feeds and Feeding."

How Plants Feed.—Every seed is made up of a germ (embryo plant) surrounded by stored up food. When a seed is dropped into the warm soil it germinates and feeds on this stored up food material until it has put forth a root, stem and leaves. It is now able to gather its food from the air, water and soil. On the roots of plants are minute root hairs, composed of single cells, which absorb food materials from the soil water, by means of osmosis or diffusion. The leaves, on the under sides, have minute openings which permit the breathing of air which contains carbonic acid gas. The carbon is used in building up the plant and the excess of oxygen is given back to the atmosphere. This process requires the presence of light as does chlorophyll (green coloring matter of plants). Plants will grow without light as long as the food supply in the seed lasts, but they will be white and will not produce seed. By the aid of sunlight the materials gathered by the root hairs and leaves are manufactured into compounds and retained by the plants.

The Food of the Plant.—The plant keeps growing until it produces seed. It may continue its growth for years as is the case with trees. In this continual growing process we cannot see the plant feeding but we know its nourishment is obtained from the soil, water and air. The food of the plant, then, consists of the mineral substances, water and gases taken from the soil and air.

Composition of Plants.—All plants are made up of water and dry matter. The water is composed of hydrogen and oxygen while the dry matter contains many elements and combinations of elements.

Water.—All plants and parts of plants contain water. The

water is present in two forms, namely, physiological and hygroscopic.

1. **Physiological water** is that which is contained in the plant structure. It is obtained from the soil. It is used to keep the leaf tissues and their cell walls moist so that carbonic acid gas may be absorbed, to transfer food materials, and to regulate the temperature of the plant by means of evaporation of water, just as the temperature of the animal body is regulated by the evaporation of perspiration. When green grass is dried in the sun the loss in weight is mostly due to evaporation of physiological water.

2. **Hygroscopic water** is that which is taken up from the air and may vary from day to day according to the humidity of the surrounding air. On rainy days more water would be taken up than on dry days. The writer has often determined the water content of the same samples of corn-meal, wheat bran, cotton-seed meal, hays, etc., on different days and found variations often of two per cent. Sometimes there is an increase and at other times a decrease of hygroscopic water, depending upon the humidity of the surrounding air. The hygroscopic moisture also varies with different plant materials.

Amounts of Water Used by Plants.—According to Whitson: "The amount of water used by plants varies greatly with the kind of plant and with climatic conditions, but is always large. For instance, in the growth of one pound of dry matter of corn about 250 to 300 pounds of water are used: for potatoes, 350 to 400 pounds: for clover, 500 to 600 pounds."

Amounts of Water Exhaled by Plants.[6]—

	Pounds of water
One acre of wheat exhales	409,832
One acre of clover exhales	1,096,234
One acre of sunflowers exhales	12,585,994
One acre of cabbage exhales	5,049,194
One acre of grape vines exhales	730,733
One acre of hops exhales	4,445,021

Variation of Water in Plants.—Some species of plants contain much more water than others and the different parts of the same plant show a great variation in water content. We have all no

doubt noticed that certain fruits like the apple, pear, lemon, plum, peach, strawberry, etc. and roots and tubers as the turnip, beet, radish, carrot, Irish potato, etc., contain a great deal of water. Perhaps some have not heretofore thought that substances like corn grain, wheat kernel, rice kernel, the several grain straws, etc., have water present. The following table gives us the percentage of water in some familiar plants and parts of plants.

Fruits	Per cent.	Forage plants (green)	Per cent.
Apple	80.0	Alfalfa	71.8
Grape	83.0	Corn	79.3
Peach	88.4	Cowpea	83.6
Pear	83.1	Sorghum	79.4
Strawberry	90.2	Timothy	61.6
Roots and tubers		Cereals and straws	
Beet (mangel)	90.9	Corn (grain)	10.6
Carrot	88.6	Oats (grain)	11.0
Irish potato	78.9	Rice (rough)	10 9
Sweet potato	71.1	Rye straw	7.1
Turnip	90.5	Wheat straw	9.6

Water in Young and Mature Plants.—The percentage of water in young plants is greater than in mature plants. This is easily accounted for because the young plant uses a great deal of water in transferring food materials required for its growth. The Maine State College conducted an investigation on timothy with the following results:[7]

	Water Per cent.		Water Per cent.
Nearly headed out	78.7	Out of blossom	65.2
In full blossom	71.9	Nearly ripe	63.3

The results on timothy are similar to what would be found with other plants. It follows that the more mature a plant is, the easier it is to field cure.

Active cells in plants contain more water than do the older or less active cells and this may account for the larger percentage of water found in young plants.

Dry Matter of Plants.—As previously stated, the plant is made up of water and dry matter. When water is driven off from

plants the dry matter is what remains. Now if we burn this dry matter a large proportion of it passes off in the form of invisible gases. This material which so disappears, in burning, is known as organic matter, that which is left is the ash or mineral matter or inorganic matter. The organic matter is composed of carbon, hydrogen, nitrogen, oxygen, etc. The ash is made up of soda, phosphorus, sulphur, iron, potassium, calcium, silicon, etc.

The following table shows the elements that make up plants.[7]

- Plants
  - Inorganic matter
    - Water
      - Oxygen
      - Hydrogen
    - Ash
      - Oxygen
      - Sulphur
      - Chlorine
      - Phosphorus
      - Silicon
      - Fluorine
      - Potassium
      - Sodium
      - Calcium
      - Magnesium
      - Iron
      - Manganese
      - Aluminum
  - Organic matter ....
    - Carbon
    - Oxygen
    - Hydrogen
    - Nitrogen
    - Sulphur (generally)
    - Phosphorus (sometimes)
    - Iron (in a few cases)

We may express the composition of plants as:

- Plants
  - Water
  - Dry matter
    - Ash
    - Organic matter

Composition of the Dry Matter of Plants.—A German scientist, Knop, estimated; according to Jordan:[7] "That if all the species of the vegetable kingdom, exclusive of the fungi, were fused into one mass, the ultimate composition of the dry matter of this mixture would be the following:"

	Per cent.
Carbon	45.0
Oxygen	42.0
Hydrogen	6.5
Nitrogen	1.5
Mineral compounds (ash)	5.0

From the above analysis it is readily seen that carbon and oxygen make up the largest proportion of plants. Let us examine the composition of some farm products that are familiar to us, and find out if this same predominance of carbon and oxygen exists.[7]

	Carbon Per cent.	Oxygen Per cent.	Hydrogen Per cent.	Nitrogen Per cent.	Ash Per cent.
Clover hay	47.4	37.8	5.0	2.1	7.7
Wheat kernel	46.1	43.4	5.8	2.3	2.4
Fodder beets	42.8	43.4	5.8	1.7	6.3
Fodder beet leaves	38.1	30.8	5.1	4.5	21.5
Wheat straw	48.4	38 9	5.3	0 4	7.0

There is some variation in the composition of these farm products but the carbon and oxygen constitute the largest amounts of the elements present.

This predominance of carbon and oxygen is due to the fact that about nineteen-twentieths of the plants' food is obtained from air and water, and the remaining one-twentieth is derived from mineral compounds of the soil and soil water. In other words the farmer only has to supply a small proportion of the elements necessary for producing good crops.

Distribution of the Mineral Elements in Plants.—Let us see the proportions of mineral elements that the plant stores up in its period of growth. This table is figured on dry matter.[8]

	Potassium	Sodium	Calcium	Magnesium	Iron	Phosphorus	Sulphur
Apple	0.43	0.28	0.04	0.08	0.01	0.09	0.04
Gooseberry	1.09	0.25	0.30	0.12	0.11	0.29	0.08
Strawberry	0.59	0.72	0.35	——	0.14	0.21	0.04
Orange	0.93	0.31	0.54	0.15	0.03	0.15	0.05
Sugar-beet	1.69	0.25	0.17	0.18	0.03	0.20	0.06
Sugar-beet leaves	3.24	1.52	2.15	1 02	0.06	0.31	0.32
Turnip	3.02	0.59	0.61	0.18	0.05	0.44	0.36
Turnip leaves	2.26	0.82	2.74	0.28	0.13	0.37	0.44
Cabbage	3.57	0.58	0.84	0.21	0.03	0.50	0.53
Cauliflower	3.07	0.37	0.33	0.19	0.06	0.74	0.44
Onion	1.49	0.10	0.86	0.15	0.08	0.40	0.12

Ash in Plants.—Although carbon, oxygen, and hydrogen make up most of the dry matter of plants the other elements are nevertheless absolutely necessary for the growth of the plant. Hall[9] illustrates the importance of these other elements by water cultures. The roots of young plants were dipped in a large jar of water in which salts of the elements found in the plant were dissolved. The following were the kinds and amounts of salts used:

	Grams per liter
Calcium nitrate	0.7
Potassium phosphate	0.6
Potassium chloride	0.8
Magnesium sulphate	0.3
Ferric chloride	trace

Hall says: "This will contain all the elements, except silicon, normally found in plant ashes, and under such conditions the plant will grow and go through its whole cycle of life, assimilating freely, producing large quantities of dry matter, setting flowers, and ripening healthy seed. Certain precautions have to be taken, but if the right conditions are assured, the growth of a plant in a water culture is perfectly normal, and may be taken, as far as the plant is concerned, as representing the course of its nutrition in the field. The advantage of the method lies in the fact that it is possible to vary the composition of the nutrient solution by omitting in turn from successive jars each of the salts used in making up the complete solution, thus obtaining media for the plant containing no nitrogen, no phosphorus, no potassium, etc., the other constituents found in the plant being present in each case." The results of such an experiment have shown that where no nitrogen was supplied, the plant was unable to grow after it had used up its stored up material in the seed, no matter how much of the other elements were supplied.

"The net result of such experiments, is that a plant must obtain by means of its root, nitrogen in combination, phosphorus, sulphur, potassium, magnesium, calcium and a little iron—all of which constituents are indispensable to the growth of the plant and cannot be omitted from the culture solutions. Sodium,

silicon and probably chlorine, though invariable constituents of the ash are not necessary and can be dispensed with. From these water culture experiments we arrive, then, at the conclusion that the plant must draw certain elements, in quantities which are small compared with the weight of the crop but are nevertheless indispensable, out of the soil by means of its roots, the rest of the plant being built up from air and water."

Acids and Bases.[5]—The mineral elements that make up the ash of plants are not present in the free state but in various combinations, as acids and bases. The acids and bases of the mineral elements of ash are:

Acids

Sulphuric (hydrogen, sulphur and oxygen) H_2SO_4
Hydrochloric (hydrogen and chlorine) HCl
Phosphoric (hydrogen, phosphorus and oxygen) $H_6P_2O_8$
Carbonic (carbon and oxygen) CO_2
Silicic (silicon and oxygen) SiO_2

Bases

Lime (calcium and oxygen) CaO
Soda (sodium and oxygen) Na_2O
Potash (potassium and oxygen) K_2O
Magnesia (magnesium and oxygen) MgO
Iron oxide (iron and oxygen) Fe_2O_3.

The mineral elements do not exist as acids and bases in the ash because in the burning of plant substances there is a rearrangement of the mineral elements and salts are formed.

Salts.—The elements exist in the ash of plants as salts. That is the acids and bases are united and form:

Phosphates Sulphates Chlorides and Carbonates	of	Calcium Magnesium Sodium Potassium

We are all familiar with some of these salts. A few of the combinations are:

Chloride of sodium (common salt)	Sulphate of soda (Glauber's salts)
Carbonate of lime (limestone)	Sulphate of magnesia (Epsom salts)
Chloride of potash (muriate of potash)	Sulphate of calcium (gypsum)
Carbonate of soda (baking powder)	Sulphate of potash (common sulphate of potash of commerce).

Variation of Ash.—The content of ash in different plants and parts of plants varies a great deal as the following table shows:

Grains	Ash Per cent.	Straw	Ash Per cent.
Corn	1.5	Oat	5.1
Oats	3.0	Rice	7.8
Rice	5.5	Rye	3.2
Wheat	1.8	Wheat	4.2
Roots and tubers (fresh)		Forage plants (hay)	
Beet (mangel)	1.1	Alfalfa	7.4
Carrot	1.0	Crimson clover	8.6
Irish potato	1.0	Orchard grass	6.0
Sweet polato	1.0	Timothy	4.4

Different parts of the same plant vary in ash content.

	Ash Per cent.		Ash Per cent.
Corn grain	1.5	Corn stover (whole plant except ears)	4.9
Corn leaves	9.7	Corn shucks	3.4
Corn (whole plant)	4.3	Corn cob	1.4
Corn germ	4.1	Corn bran	1.3

There is also a variation in the amounts of compounds in the ash of different parts of the same plant. The percentages of the compounds in this table are figured on 100 per cent. ash of sugar-cane.[10]

	Ash of leaves Per cent.	Ash of stalk Per cent.	Ash of roots Per cent.
Potash	31.25	38.23	17.39
Soda	1.17	1.30	0.85
Lime	5.90	5.19	3.45
Magnesia	5.11	5.76	2.61
Iron oxide	1.45	1.13	3.60
Alumina	1.03	0.25	4.70
Silica	30.32	15.70	49.52
Phosphoric acid	7.25	5.27	3.99
Sulphuric acid	11.29	18.47	9.15
Carbonic acid	1.10	2.70	0.45
Chlorine	3.08	4.52	0.98
Carbon	0.16	0.54	2.30
Ash	2.23	0.64	1.87

From the figures given in the foregoing tables we find that the leaves of plants contain the most ash. The straws contain more ash than the grains.

Let us see the relation of the ash of roots to the leaves of the same plant.

	Roots Per cent. ash	Leaves Per cent. ash
Sugar-beet	3.83	14.88
Stock turnip	8.01	11.64

The per cent. of ash in seeds is generally less than in the plant from which they are derived.

	Ash Per cent.		Ash Per cent.
Sorghum seed	2.1	Sorghum fodder	4.6
Cowpea seed	3.2	Cowpea hay	7.5
Soy bean seed	4.7	Soy bean hay	7.2

MINERAL ELEMENT IN VEGETABLE SUBSTANCES. (Dry Basis.)

	Ash	Potassium	Sodium	Calcium	Magnesium	Iron	Phosphorus	Sulphur
Barley	1.99	0.27	0.06	0.01	0.15	0.02	0.29	0.02
Corn	1.45	0.36	0.01	0.02	0.14	0.08	0.29	0.004
Oats	3.12	0.46	0.04	1.08	0.14	0.03	0.35	0.02
Rice	0.39	0.07	0.02	0.01	0.03	0.003	0.09	0.001
Winter wheat	1.96	0.51	0.03	0.05	0.14	0.02	0.40	0.003
Alfalfa (in bloom)	7.38	1.44	0.10	2.15	0.22	0.10	0.27	0.17
Red clover (in bloom)	6.86	1.84	0.10	1.71	0.45	0.05	0.29	0.09
White " (in bloom)	7.32	1.31	0.39	1.58	0.42	0.11	0.41	0.22
Soy beans	3.14	1.16	0.02	0.12	0.17	—	0.50	0.03
Blue grass	5.18	1.81	—	0.18	0.10	—	0.22	0.10
Timothy	6.82	1.96	0.09	0.39	0.13	0.04	0.35	0.08
Corn stover	5.33	1.61	0.05	0.41	0.18	0.09	0.19	0.11
Oat straw	7.17	1.72	0.18	0.36	0.16	0.06	0.14	0.09
Wheat straw	5.37	0.61	0.06	0.22	0.08	0.02	0.11	0.05
Potato	3.79	1.89	0.08	0.07	0.11	0.03	0.28	0.10
Radish	15.67	2.86	0.44	0.98	0.35	0.13	2.81	0.48
Sugar-beet	3.83	1.69	0.25	0.17	0.18	0.03	0.20	0.06
Sugar-beet leaves	14.88	3.24	1.52	2.15	1.02	0.06	0.31	0.32
Turnip	8.01	3.02	0.59	0.61	0.18	0.05	0.44	0.36
Turnip leaves	11.64	2.26	0.82	2.74	0.28	0.13	0.37	0.44
Cabbage	9.62	3.57	0.58	0.84	0.21	0.03	0.50	0.53
Cauliflower	8.35	3.07	0.37	0.33	0.19	0.06	0.74	0.44
Rape	8.10	2.23	0.20	1.27	0.19	0.07	0.39	0.45
White beans	3.22	1.18	0.04	0.15	0.15	0.01	0.50	0.05
Corn-meal	0.68	0.16	0.02	0.03	0.06	0.02	0.13	—
Cotton-seed meal	7.48	1.85	—	0.24	0.69	0.07	1.50	0.04
Patent flour	0.51	0.15	0.003	0.03	0.03	0.002	0.11	—
Linseed meal	5.84	1.18	0.06	0.35	0.56	0.11	0.81	0.08
Rice bran	6.08	0.56	0.10	0.09	0.64	0.23	1.14	0.01
Wheat bran	6.16	1.46	0.03	0.13	0.66	0.03	1.35	0.002

The per cent. of ash and the mineral elements that constitute the ash are given for several vegetable substances in the foregoing table.[8]

Occurrence of Mineral Elements in Plants.—According to Forbes;[8] "Mineral substances of foodstuffs are present in four mechanical conditions: 1. In solution in the plant juices; 2. as crystals in the tissues; 3, as incrustations in cells and 4, in chemical combination with the living substance.

"The mineral content of any species of plant varies considerably as affected (1) by the composition of the soil and the soil water, (2) by the various factors controlling transpiration of water by the plant and (3) by the loss of mineral substance either through shedding of parts or through the leaching effect of dews and rains."

Distribution of Ash in Plants.—Roots and seeds generally contain much less ash than leaves because the mineral elements are carried to the leaves for the elaboration (manufacturing) of food and then the water evaporates and the ash remains. The ash present in roots and seeds is usually needed for supporting germination and early growth of the plant, while some of that in the leaves is in excess of what is really needed.

Phosphorus and potassium are present in the largest amounts in seeds, followed by magnesia. Silicon and potassium predominate in cereal grasses and straws, and the per cent. of calcium is usually larger than phosphorus or magnesium. The leguminous crops (alfalfa, clovers, cowpeas, soy beans, etc.) contain more calcium than phosphorus or potassium. Roots and legumes contain much less silicon than straws.

Ash of Young and Mature Plants.—According to Wolff the per cent. of ash of the dry matter of wheat, oats, rye, and clover decreases with the growth of the plant. The ash of healthful plants is generally higher in calcium than in sickly plants. The per cent. of calcium and potassium in the ash of grass plants decreases in the growing of the plant and the silicon increases. In the ash of the dry matter of clover, the magnesium and calcium increase while the potassium decreases.

CHAPTER II.

THE FERTILITY OF THE SOIL.

The fertility of the soil is shown in the crops produced and a soil is said to be fertile when profitable crops are grown under favorable conditions.

Composition of Soils.—In order to understand the conditions which affect fertility let us become familiar with the composition of soils. Soils are made up of disintegrated (ground) rocks and decayed plant and animal life. Some soils, like sandy soils, predominate in rock particles while peaty soils are rich in decayed plant material. Most soils contain both ground rocks and decayed plants.

Inorganic Matter.—That part of the soil composed of ground rocks (sand, silt, clay, etc.) is called inorganic matter and corresponds to some extent to the ash, or non-combustible, or inorganic matter in plants. Of course the particles of inorganic matter in the soil may be different from the original rocks from which they were derived, due to the action of rain, frost, sun, etc., yet we find that a considerable portion of these particles is often of the same composition as the original rocks.

Organic Matter.—The decaying vegetable or animal matter in the soil is called organic matter. It is that part of the soil which is driven off when burned and corresponds to the organic matter in plants. Most of the organic matter in soils comes from decaying vegetation. When this decaying vegetable or animal matter becomes thoroughly decomposed it assumes a black waxy consistency and is called humus. This humus is a very important constituent and influences to a great extent the physical and biological condition of soils.

The amount of organic matter in soil influences its water holding capacity, texture, temperature, color, supply of available plant food and general productiveness.

Factors Influencing Soil Fertility.—There are many factors influencing soil fertility and these may be summed up under the following heads:

1. The available supply of plant food.
2. The physical condition of the soil.
3. The biological condition of the soil.

1. **The Plant Food Supply.**—It may be surprising to know that most farm soils, even those that produce poor crops, are abundantly supplied with plant food. The following table shows the supply of plant food in representative soils.

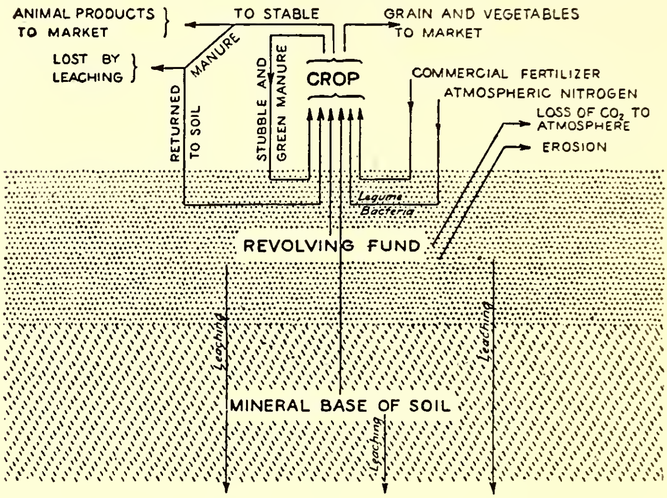

Fig. 1.—Indicating the factors which influence soil fertility—after Whitson.

NATIVE PLANT FOOD IN FARM SOILS.[11]

Location	Nitrogen per cent.	Phosphoric acid, per cent.	Potash per cent.	Pounds of nitrogen in first 8 inches of soil	Pounds of phosphoric acid in first 8 inches of soil	Pounds of potash in first 8 inches of soil
Alabama	0.195	0.196	0.183	4,218	4,240	3,959
Alabama	0.282	0.267	0.866	6,436	6,094	19,756
Canada	0.048	0.140	0.250	1,112	3,244	5,793
Canada	0.114	0.130	0.390	2,638	3,008	9,024
Colorado	0.040	0.230	0.230	872	5,016	5,016
Connecticut	0.334	0.038	0.056	7,224	822	1,211
Connecticut	0.140	0.051	0.047	2,971	1,082	997
Michigan	0.110	0.280	1.950	2,455	6,250	43,526
Michigan	0.070	0.210	1.100	1,484	4,451	23,314
Missouri	0.140	0.080	1.320	3,012	1,721	28,395
Missouri	0.130	0.070	2.540	2,814	1,515	54,986
Nebraska	0.070	1.420	0.197	1,530	31,062	4,306
Nebraska	0.073	0.062	0.741	1,581	1,334	15,938
New York	0.204	0.115	0.960	4,362	2,460	20,532
New York	0.130	0.160	0.510	3,074	3,784	12,063

The above analyses show from 872 to 7,224 pounds of nitrogen, 822 to 31,062 pounds of phosphoric acid and 997 to 54,986 pounds of potash per acre.

Chester of the Delaware Agricultural College, states:[1] "An average of the results of 49 analyses of the typical soils of the United States showed for the first eight inches of surface, 2,600 pounds of nitrogen, 4,800 pounds of phosphoric acid and 13,400 pounds of potash. The average yield of wheat in the United

PLANT FOOD REMOVED BY CROPS IN POUNDS PER ACRE.[12]

Crop	Gross weight	Nitrogen	Phosphoric acid	Potash	Lime
Wheat, 20 bu	1,200	25	12.5	7	1
Straw	2,000	10	7.5	28	7
Total		35	20.0	35	8
Barley, 40 bu	1,920	28	15	8	1
Straw	3,000	12	5	30	8
Total		40	20	38	9
Oats, 50 bu	1,600	35	12	10	1.5
Straw	3,000	15	6	35	9.5
Total		50	18	45	11.0
Corn, 65 bu	2,200	40	18	15	1
Stalks	6,000	45	14	80	20
Total		85	32	95	21
Peas, 30 bu	1,800	..	18	22	4
Straw	3,500	..	7	38	71
Total		..	25	60	75
Flax, 15 bu	900	39	15	8	3
Straw	1,800	15	3	19	13
Total		54	18	27	16
Meadow hay	2 000	30	20	45	12
Red clover hay	4,000	..	28	66	75
Potatoes, 300 bu	18,000	80	40	150	50
Mangels, 10 tons	20,000	75	35	150	30

States is 14 bushels per acre. Such a crop will remove 29.7 pounds of nitrogen, 9.5 pounds of phosphoric acid and 13.7 pounds of potash. Now if all the potential nitrogen, phosphoric acid and potash could be rendered available, there is present in such an average soil, in the first eight inches, enough nitrogen to last 90 years, enough phosphoric acid for 500 years and enough potash for 1,000 years."

On page 19 the amount of nitrogen, phosphoric acid potash and lime removed per acre by some of our leading farm crops are given.

From these figures it is evident that all of the above soils have sufficient amounts of plant food to last for many years. Corn yielding 65 bushels per acre, only takes away 85 pounds of nitrogen, 32 pounds of phosphoric acid and 95 pounds of potash. Mangels which are heavy users of potash only show a removal of 150 pounds for a ten ton crop. When we compare the amounts of these constituents removed by crops and the total supply in the average soil we may better realize the amount of stored up plant food in soils.

Hall states:[9] "That an average soil contains enough plant food for one hundred full crops, yet without fresh additions of plant food as manures the production will shrink in a very few years to one-third or one-fourth of the average full crop. Once, however, the yield has reached this lower level, it will remain for an indefinite period comparatively stationary, affected only by the fluctuations due to season. At Rothamstead (Experiment Station in England) for example, wheat has now been grown year after year on the same land for sixty-five seasons, and one plot has received no manure throughout the whole period. In the first few years the crop declined steadily, but since then little or no further drop has been seen. The yield remains about 12½ bushels per acre for each successive ten years' average, and has considerably overtopped that amount during recent favorable seasons. This yield, however, of 12½ bushels per acre, is only about one-third of that obtained on adjacent plots receiving manure every year during the same period."

Plant Food not Available.—The question naturally arises, what is the use of adding fertilizers or manure to soils when such large amounts of plant food are present? The plant food in the soil is dormant; it is locked up; it is unavailable. Available plant food may be present but the condition of the soil may be such that the plant cannot utilize it. The soil may be acid or sour, or it may contain objectionable substances distasteful to plants.

The plant obtains its nourishment from the salts in solution in the soil water and these soluble salts constitute the available plant food. The chemist can determine the total plant food, or the potential fertility, in the soil, but he cannot tell us how much is available. The available plant food supply may be ascertained, to a certain extent, by carrying on field experiments. The results of such experiments will of course vary with different soils and different crops. The chemist can determine whether a soil is acid, alkaline or neutral and from such data advise whether lime would benefit the soil, the amount to apply and the kind of fertilizers to use. In such cases a chemical analysis is exceedingly valuable but ordinarily field trials with crops prove the better way of determining productiveness.

The Essential Elements.—In the preceding chapter the elements needed by plants were discussed and the composition of plants given. From the composition of plants aided by field experiments it has been possible to learn that certain elements are necessary for plant growth. From this data it has been ascertained that only three and sometimes four elements are required to be furnished the plant for its complete development, as the other elements are fortunately present in sufficient quantities in the air and the soil so that we need not consider them. Nitrogen (N), phosphorus (phosphoric acid P_2O_5) and potassium (potash K_2O) are the elements usually exhausted most readily from the soil, and occasionally calcium (lime, CaO). Because of the necessity of adding nitrogen, phosphoric acid and potash for the growth of most crops the name "essential" is applied to these elements, and the remaining elements are termed "un-

essential." The essential elements, nitrogen, phosphoric acid and potash are usually found in larger amounts in plants and in smaller quantities in soils than the other elements. Nitrogen and phosphoric acid are usually more liable to be deficient than potash, and lime is only occasionally lacking. The term fertilizers is applied to materials containing any or all of these essential elements, in available form, and are supposed to make up for the deficiencies in the soil. Fertilizers may contain other elements as magnesia, sulphuric acid, etc., though needed by the plant are unessential as the soil contains a sufficient amount for crops.

The fifteen elements used by plants may be classified as:

Elements sometimes lacking in the soil	Elements obtained from the air or water	Elements that are present usually in sufficient amounts
Nitrogen	Hydrogen	Calcium (usually)
Phosphorus	Oxygen	Iron
Potassium	Carbon	Sulphur
Calcium (occasionally)	Nitrogen (sometimes)	Magnesium
		Silicon
		Sodium
		Chlorine
		Manganese
		Aluminum.

One Element Cannot Replace Another.—It must be understood that no one of these essential elements can take the place of another, as each has its particular functions to perform which are different for each element. Therefore should a soil be deficient in any of these essential elements, the addition of those that are lacking will tend to produce good crops, provided other conditions are favorable. Let us illustrate this by supposing we wish to plant a field of corn. We have perhaps plenty of available phosphoric acid, potash and lime for the needs of the corn and the land is in good condition, but the available supply of nitrogen is deficient in the soil. We cannot grow a profitable crop of corn under such conditions because the phosphoric acid, potash and the lime are unable to take the place of the nitrogen, no matter how abundant they may be. Should nitrogen be

supplied in sufficient amount the crop would be satisfied and should prove profitable, other conditions being right.

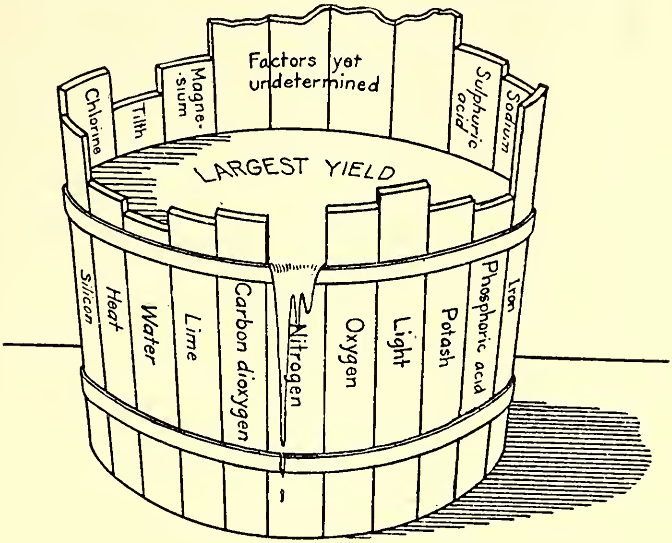

Fig. 2.—Illustration of the principle of limiting factors in soil fertility —after Dobenecks, from Whitson.

It has been found that sodium and potassium may replace each other, to a limited extent, in correcting the acidity that may take place in plants, although they cannot replace each other in supplying plant food. There are some elements which have common functions, but each element has its work to perform for the complete development of plants.

2. **Physical Condition of the Soil.**—There are some soils which contain sufficient amounts of available plant food for the needs of crops but this food cannot be utilized because of other factors which affect the physical condition of soils. Some of these factors will be briefly discussed.

Temperature.—The temperature of the soil depends upon the heat of the air and the nature of the soil. It is a very important consideration in plant growth. The following table gives soil temperatures for hourly periods at a depth of one foot from the surface.[13]

	June 1.—Readings in two-hour periods											
	6	8	10	N	2	4	6	8	10	M	2	4
Clay loam, Pennsylvania	60.5	61.0	61.0	61.3	62.0	62.5	63.0	63.5	63.6	63.6	63.3	63.0
Loam, Pennsylvania	—		61.0	60.3	60.3	60.6	61.2	61.7	62.0	62.1	62.1	62.1
Silt loam, North Carolina	72.0	70.0	70.0	69.8	70.0	69.8	69.7	69.5	69.3	69.0	68.5	68.0
Sandy loam, North Carolina	72.5	71.0	69.5	69.8	69.5	69.2	69.0	69.0	68.8	68.0	67.5	67.2

	June 2.—Readings in two-hour periods											
	6	8	10	N	2	4	6	8	10	M	2	4
Clay loam, Pennsylvania	62.8	62.5	62.5	62.7	63.0	64.0	64.5	65.0	65.0	65.0	64.8	64.5
Loam, Pennsylvania	62.0	61.8	61.5	61.4	61.3	61.8	62.2	62.8	63.3	63.3	63.3	63.2
Silt loam, North Carolina	68.0	67.3	67.2	67.2	67.8	68.3	68.7	68.8	68.8	68.5	68.0	67.8
Sandy loam, North Carolina	67.0	66.5	66.0	66.5	67.5	68.2	68.8	69.0	68.7	68.3	68.0	67.5

The germination of seed, the transference of soil water, which contains the available plant food, the movement of soil air, the development of organisms are all greater when the soil is warm. The coarser soils seem to warm up more readily than the heavy clays. The location of the land influences soil warmth. A soil with a southern exposure is naturally warmer than one with a northern location.

In the following table are given the average mean monthly range in temperature of the air and soil for twelve years at Lincoln, Nebraska.[13]

Depth	January	February	March	April	May	June	July	August	September	October	November	December
Air	25.2	24.2	35.8	52.1	61.9	71.0	76.0	74.5	67.6	55.5	38.7	28.3
Soil, 1 inch..	27.3	27.7	38.2	57.5	68.7	78.1	85.1	82.9	73.8	56.7	38.7	31.6
Soil, 6 inches	28.6	27.8	36.6	53.3	65.1	75.7	81.6	80.1	72.0	57.8	41.5	32.0
Soil, 12 inches	31.3	30.2	35.4	49.3	60.7	69.9	75.7	75.7	69.2	57.8	44.7	35.2
Soil, 36 inches	38.5	35.5	35.8	43.8	53.5	61.3	67.4	69.8	67.6	61.3	52.2	43.3

The effect of the summer sunshine shows that the upper soil is warmer in summer than the lower or deeper soil. In winter the deeper soil is warmer than the surface soil. This shows the effect of the temperature of the air on soil warmth.

Mechanical Composition.—Should we examine a few different soils we would find that there is a great difference in the size of the particles or grains that make them up. For example, when lumps of different soils are broken up and passed through sieves of various sizes, or shaken in bottles with water, particles varying in size from gravel to fine dust are apparent. The grains or particles of soil are usually classified into four groups; gravel, sand, silt and clay. Sandy soils predominate in the largest particles, gravel and sand, alluvial or silt soils contain more particles the size of silt, and clay soils have more of the finest particles, clay. It should be understood that all soils contain large and small particles. A loam soil contains all the particles in about equal proportions.

The Bureau of Soils of the United States Department of Agriculture has adopted the following measurements for the size of soil grains.

Fine gravel	2.0 to 1.0	millimeters
Coarse sand	1.0 to 0.5	millimeters
Medium sand	0.5 to 0.25	millimeters
Fine sand	0.25 to 0.10	millimeters
Very fine sand	0.10 to 0.05	millimeters
Silt	0.05 to 0.005	millimeters
Clay	0.005 to 0.0000	millimeters

MECHANICAL ANALYSES OF SOME SOILS.[14]

	Coarse barren sand	Coarse sandy loam	Fine sandy loam	Heavy clay loam	Heavy clay
Fine gravel, 3 to 1 mm.	0.2	7.6	0.5	2.8	0.4
Coarse sand, 1 to 0.2 mm.	22.6	44.9	15.0	14.1	0.8
Fine sand, 0.2 to 0.05 mm.	60.8	23.1	49.0	31.2	6.4
Silt, 0.05 to 0.01 mm.	4.8	4.3	15.3	17.4	18.6
Fine silt, 0.01 to 0.005 mm.	0.6	2.9	3.9	6.9	13.6
Clay, below 0.005 mm.	1.8	11.7	9.7	18.5	42.2

The percentages of moisture, humus and carbonate of lime are not included in the mechanical analyses of soils.

Surface Area of Soil Grains.—The surface area of soil grains varies with the size of the particles. The smaller the grains the more surface area is exposed to the action of water and soil organisms, and the more quickly is plant food rendered available.

Diameter of grain	Square feet of surface in a pound
Coarse sand, 1 mm	11.05
Fine sand, 0.1 mm	110.54
Silt, 0.01 mm	1,105.38
Clay, 0.001 mm	11,053.81
Fine clay, 0.0001 mm	1,100,538.16

Relation of Mechanical and Chemical Composition.—The following table gives the chemical composition of different classes of soils.[15]

Conventional name	Clay	Finest silt	Fine silt	Medium silt	Coarsest silt
Per cent. present in soil	21.64	23.56	12.54	13.67	13.11
Diameter of particles	0.011-0.000 mm.	0.005-0.011 mm.	0.013-0.016 mm.	0.022-0.027 mm.	0.033-0.038 mm.
Constituents	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Insoluble residue	15.96	73.17	87.96	94.13	96.52
Soluble silica (SiO_2)	33.10	9.95	4.27	2.35	..
Alumina (Al_2O_3)	18.19	4.32	2.64	1.21	..
Ferric iron (Fe_2O_3)	18.76	4.76	2.34	1.03	..
Phosphoric acid (P_2O_5)	0.18	0.11	0.03	0.02	..
Sulphur trioxide (SO_3)	0.06	0.02	0.03	0.03	..
Lime (CaO)	0.09	0.13	0.18	0.09	..
Magnesia (MgO)	1.33	0.46	0.26	0.10	..
Soda (Na_2O)	—	0.24	0.28	0.21	..
Potash (K_2O)	1.47	0.53	0.29	0.12	..
Volatile matter	9.00	5.61	1.72	0.92	..
Totals	99.84	99.30	100.00	100.21	96.52
Total soluble constituents in acid	75.18	20.52	10.32	5.16	

The results given in this table show that clay contains more plant food than finest silt; finest silt more than fine silt and fine silt more than medium silt. In other words the finer the particles in a soil the more total plant food is present. There is also more soluble silica and alumina in the finer soils.

Lumpy Soils.—The mechanical composition of a soil is important, for the farmer to consider, in order to keep the soil receptive for growing crops. The clustering or lumping of soils is brought about by the adhering of the particles due to the surface tension of the films of water surrounding the grains. As the water dries out the grains are held together with the aid of the salts in solution. Fine soils, like clay, contain many more particles than sandy soils, so it is apparent that clay soils are more apt to form lumps than the coarser soils.

Cracking of Soils.—When soils become dry the films of water around the soil particles become thinner and the soil contracts, breaking in the weakest point, causing cracks.

Puddling of Soils.—If soils are worked when in a very wet condition the soil particles run together and a puddled soil is formed. After such a soil, especially a clay soil, dries out it becomes very hard and most difficult to restore to good condition. A farmer should never work a clay soil when it is too wet.

Freezing and Thawing.—When soils are plowed deeply in the fall and allowed to be acted upon by the frosts a helpful crumb like condition results. The action of frosts is more apparent when northern and southern soils are compared. The northern soils treated as above are usually in better tilth than the southern soils in sections of little or no frost.

Plants are Benefited by Open Soils.—A good tilth of the soil helps the plant a great deal in securing its food, and is therefore an important factor in the production of crops. A soil should be compact enough to support the plant in an upright position, but if it is too compact the young plant has to overcome a great deal of resistance in securing its food.

Plants Must Have Room.—Only a certain number of plants can be grown successfully on a given space of land. We have only to examine the root development of mature plants to learn the spreading tendency of plants. If plants are too crowded, imperfect development is the result. The roots of plants spread somewhat and the distance apart is regulated to some extent by the available plant food, the nature of the plant and the tillage of the soil. In the foreign countries more plants are usually grown on a given area than in America but the land is perhaps more thoroughly tilled, because land is high in price and labor cheap, while in America land is comparatively cheap and labor high. In well tilled soils roots go deeper and do not spread so much as in soil in poor condition.

Plants Require Oxygen.—A soil that is too compact will not permit of the free circulation of air. When air is excluded from the soil, free oxygen which is absolutely necessary for growth is excluded. It has been shown that when air is not freely supplied to plants they become sickly and growth is retarded.

When a soil becomes water-logged, plants will not grow and if the condition continues the plants will die. Some plants will grow in water but the water must be fairly free from soil so as to be able to absorb and diffuse oxygen from the air. It has been found that 40 to 60 per cent. of the water holding capacity of soils is the best amount and 80 per cent. is injurious.

Drainage.—Good crops cannot be grown unless the land is well drained, either naturally or artificially. A certain amount of water is essential for crops, but a water-logged condition must be avoided to secure good results.

Capillary Water.—In the preceding chapter we learned that crops use a great deal of water, the clover crop for example exhales as much as 1,096,234 pounds per acre. Crops usually rely on capillary water for their supply of this constituent. The upward movement of water in the soil is termed capillary moisture or capillary water, and is caused by the surface tension of the films of water around the soil particles becoming greater as evaporation from the upper surface of the soil takes place. One of the most important problems in farming is to conserve this soil moisture and prevent its evaporation.

Amounts of Capillary Water Held by Soils.—Sandy soils hold very little capillary water. After a rain it is estimated that 5 to 10 per cent. by weight of the soil will be water. Sandy loams and silt loams retain 15 to 20 per cent. and heavy clay soils 30 to 50 per cent. Heavy clay soils are suitable for grass lands because of this power of holding water, as grasses require considerable water for maximum growth.

How to Prevent Loss of Capillary Water.—As capillary water is so important for the welfare of crops we should learn how to prevent its loss. Water will follow along the path of least resistance. So if we form a soil mulch by cultivating or stirring the soil to the depth of two or three inches we will offer resistance to the upward movement of water. The soil should not be cultivated too deeply because some of the small roots are liable to be injured.

How to Increase the Upward Movement of Capillary Moisture.—When seed are planted in dry seasons it is often advisable to bring up the water to aid in their germination. This may be accomplished by rolling the soil thus making it firmer. After rolling it is important to form a soil mulch again to prevent the loss of all the water.

The following table may be interesting in that it gives us some idea of the rate of the upward movement of water in different dry soils.[13]

	Time							
	Min.	Hours		Days				
	15	1	2	1	3	8	13	19
	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
Silt and very fine sand	2.7	4.7	7.0	20.0	30	45.0	52.0	56.0
Very fine sand.......	7.6	10.0	12.4	21.0	23	26.0	27.5	28.5
Fine sand............	9.0	9.5	10.0	11.6	13	14.3	15.2	16.0
Coarse and medium sand	5.8	6.0	6.3	7.5	9	10.0	11.5	12.5
Fine gravel	4.0	5.0	5.3	6.4	8	9.0	10.0	10.8

3. **The Biological Condition of the Soil.**—All cultivated productive soils are full of organisms, both animal and vegetable, which aid in furnishing plant food. There are many different organisms whose functions vary a great deal. Most of these organisms are so small that they cannot be seen without the aid of the microscope, while some, with which we are all familiar, are large.

The rodents, worms and insects all have their place in stirring the soil although the rodents and some of the insects are injurious to crops. Plant roots are beneficial in that they leave organic matter in the soil and openings for the access of water and air.

The organisms we are most interested in are the bacteria

(minute plants) because of their beneficial effect in crop production.

The number of bacteria in the soil depends upon its physical condition. Water-logged soils, sandy soils, acid soils, and soils low in organic matter contain very few and sometimes no bacteria. Soils rich in humus, contain sometimes as high as 100,000,000 bacteria per gram,[1] while the average well cultivated soil contains 1,000,000 to 5,000,000 per gram. The cold winters of the north decrease the number of bacteria but these multiply during spring and summer.

The following table shows the number of bacteria found in a gram of soil during some part of the growing period.[13]

State	Soil	Crop	Investigator	Number
Delaware	——	Grass, 12 yrs.	Chester	425,000
Delaware	——	Grass, 4 yrs.	Chester	425,000
Delaware	——	Clover following fallow	Chester	1,880,000
Delaware	Rich garden	Vegetables	Chester	1,860,000
Delaware	——	Woodland	Chester	70,000
Kansas	Loam (2.19 per cent. humus).	——	Mayo & Kinsley.	33.931,747
Kansas	Loam (3.07 per cent. humus).	——	Mayo & Kinsley.	53,596,060
Kansas	Thin soil, gumbo subsoil	——	Mayo & Kinsley.	78,534
Kansas	Loam, low in humus	——	Mayo & Kinsley.	8,543,006
Kansas	Loam, low in humus	——	Mayo & Kinsley.	3,192,131

Nitrification.—Certain bacteria have the power of converting the organic nitrogen present in animal and vegetable matter into ammonia. No doubt you are all familiar with the ammonia smell around fermenting manure. This is the result of the action of bacteria. The same action that takes place in the manure heap occurs in the soil when organic matter is present. When the ammonia is formed another kind of bacteria seizes it and changes the ammonia into nitrous acid or nitrites, and this latter

[1] One ounce = 28.35 grams.

compound is in turn attacked by another organism and converted into nitric acid or nitrates. In this latter form it is readily dissolved by the soil water and available as plant food. There is a continual cycle of the forms of nitrogen. The plant

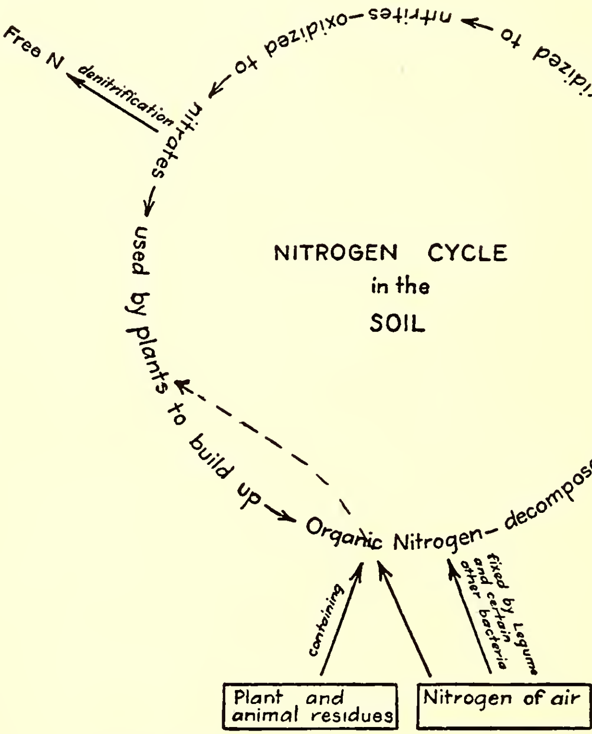

Fig. 3.—The nitrogen cycle in the soil—after Whitson.

uses the nitrogen in the form of nitrates, converts it into organic nitrogen, and when the plant dies it may be returned to the soil to go through the same process again.

Manure or other organic matter helps nitrification as is shown in the following:[13]

	Nitrates in parts per million, dry soil	
	Unmanured soil	20 tons manure per acre for three years
Land in timothy		
April 23	8.2	21.0
May 3	4.1	4.6
May 14	3.3	4.5
May 30	2.0	4.0
June 1	2.4	2.0
June 13	0.8	1.1
June 20	1.3	3.0
July 24	2.2	2.8
August 14	1.8	3.0
Land in maize		
May 19	17.5	20.1
June 22	42.8	79.3
July 6	50.0	105.0
July 28	195.0	304.0
August 10	151.0	184.0

Keeping the soil well open so that a liberal supply of air may permeate it has a beneficial effect on nitrification.[13]

Date of Analysis	Nitrates in dry soil, parts per million	
	Unaërated	Aërated
When taken from field	3.2	3.2
After standing one month	4.2	17.6
After standing two months	9.0	45.6

The more porous the soil the deeper nitrification occurs.

Dentrification.—There are some bacteria that set free nitrogen. These bacteria exert a reducing action rather than an oxidizing one. Some reduce nitrates (nitric acid) to nitrites (nitrous oxide) and ammonia. Others reduce nitrates to nitrites and then to free gaseous nitrogen. It has been found that there are more denitrifying organisms than nitrifying bacteria, although the loss of nitrogen from well drained and tilled soils is not large, because the denitrifying bacteria cannot attack the nitrogen in such soils. The nitrogen wasting bacteria work considerable damage in manure heaps.

Organisms that Gather Nitrogen.—Other organisms found in the soil that exert an effect on its fertility are those that live in the tubercles or nodules on the roots of certain plants called the legumes, of which cowpea, bean, pea, clovers, alfalfa, vetch, etc. are examples. These plants through the action of these bacteria have the power of acquiring the free gaseous nitrogen from the air and utilizing it in their growth. The bacteria secure this free nitrogen from the air in the soil and the plant acquires it from the bacteria. When the plant dies the nitrogen left in the roots remains in the soil and thus enriches it. The particular bacterium can only attach itself to the legume it is suitable to. That is, bacteria forming tubercles on the roots of clover will not grow on cowpea roots. When there is a plentiful supply of nitrogen as nitrates in the soil the legumes will not always form tubercles and utilize the free atmospheric nitrogen, but will gather their supply from the soil. Legumes therefore are able to secure nitrogen from the soil and the air. The tubercles seem to form better in alkaline soils containing lime.

Inoculation of the Soil.—The absence of tubercles on the roots of legumes may therefore be due to the absence of the particular bacteria required, to the excess of nitrates, or to the acidity of the soil. Should the soil be deficient in the particular bacteria needed, the soil should be inoculated. This inoculation is accomplished by sowing soil from a neighboring field that has produced a good crop of the kind desired, or if such a soil cannot be obtained, by inoculating the seed before planting with a pure culture which has been obtained from the tubercles of the kind of crop to be raised. These cultures may be obtained from the United States Department of Agriculture and dealers in seeds. In using soil from another field for inoculating, fungus diseases, insects and objectionable weeds are often introduced which become a serious menace in the production of crops. Care must be taken to secure soil from a disease free field. The pure cultures are not always satisfactory, as they are hard to preserve in transportation, so that the use of soil is perhaps the better method just now.

CHAPTER III.

MAINTAINING SOIL FERTILITY.

As the fertilizer ingredients, nitrogen, phosphoric acid and potash are the plant food elements that have to be supplied, let us find out some of the ways they are taken away from the soil and methods of preventing and restoring their loss.

Erosion is the loss of soil by the action of water or wind.

Any one who has ever lived in the South is familiar with the tremendous losses of fertility incurred by erosion. The most serious losses occur on hilly clay soils. Cotton and corn are grown on many of the southern soils year after year and the soil is left bare during the winter. These soils are not plowed very deep and when a heavy rain comes only a small amount of the water can soak into the soil. If the land is hilly the rain forms little rills at first which finally become gullies and much of the good fertile soil is washed to the valleys or bottom lands. In a few seasons a great deal of such hill land becomes unproductive.

There are other sections in America besides the South where erosion is damaging farms. In some of the far western states and other sections where the land is hilly, erosion is a source of loss of fertility.

Erosion by water besides carrying away the most fertile part of the soil puts the land in such a condition that it is difficult to operate. Gullies are objectionable in growing crops.

On light sandy soils the blowing away of the surface soil by wind often results in serious losses of fertility. Mounds or ridges are often formed which interfere with cultivating the soil.

Ways to Check Erosion.—Plowing up and down hill is very bad practice as the furrows become regular waterways during a rain storm. In the South the lands that are subject to erosion are usually the clay soils which will not absorb water readily. Shallow plowing is practiced and deep plowing will cause more water to be absorbed and retained. Most of these soils are lacking in organic matter. By growing green crops in the winter

and turning them under in time for the summer crops, erosion will be stopped considerably during the winter and much organic matter will be supplied which will make clay soils more porous and spongy. Underdrainage prevents erosion by carrying the excess of water away gently.

Many farmers terrace their soil to prevent it from washing away. This custom is not as beneficial as deep plowing, plowing under of green crops, or putting the land in pasture. Many of the most successful farmers keep their rows level so when it rains the water remains in the furrows instead of washing down hill. These furrows will not be straight but answer the purpose of saving fertility.

Drainage.—The loss of fertility by drainage is chiefly concerned in the loss of nitrogen. This element to be favorable for most plants to assimilate must be in the form of nitrates which are readily soluble in water. Phosphoric acid and potash are fixed in the soil so that they are insoluble in water and hence very inappreciable amounts are lost by drainage. The following table gives the composition of drainage waters from twelve plots upon which wheat was grown. These plots each possessed a tile drain at the depth of 2 feet to 2 feet 6 inches running down the center.

Lime and sulphuric acid were carried away more than the other constituents and small amounts of potash and nitrogen as ammonia were lost. Nitrogen as nitrates show considerable loss while phosphoric acid was only present in drainage water in traces.

Experiments have shown that the loss of nitrogen by drainage is greater on soils that are idle than on cultivated soils. At first thought one would suppose that the loss would be greater on the cultivated soils as they are more open and porous and hence permit of a more free passage of water through the soil.

The excess of nitrates in cultivated soils is carried down in the soil but after a rain the capillary water carries it up again to the plant roots. Again, the plants are continually using up

COMPOSITION OF DRAINAGE WATERS IN PARTS PER MILLION. (Voelcker.)[16]

Plot	2	3 × 4	5	6	7	9	10	11	12	13	14
			Minerals				400 lbs. ammonia salts				
								+ Superphosphate			
Fertilizing	Manure	o	o	+ 200 lbs. ammonia salts	+ 400 lbs. ammonia salts	+ 550 lbs. nitrate of soda	o	o	+ Sulphate of soda	+ Sulphate of potash	+ Sulphate of magnesia
Organic matter	26.1	22.9	19.3	25.7	34.9	26.7	33.6	38.4	29.3	45.3	56.1
Nitrogen as nitric acid	16.1	3.9	5.1	8.5	14.0	18.4	13.9	15.3	15.1	17.4	19.2
Nitrogen as ammonia	0.16	0.12	0.13	0.20	0.07	0.24	0.08	0.17	0.30	0.16	0.09
Lime	147.4	98.1	124.3	143.9	181.4	118.1	154.1	165.6	191.6	201.4	226.7
Magnesia	4.9	5.1	6.4	7.9	8.3	5.9	7.4	7.3	6.6	9.3	11.6
Potash	5.4	1.7	5.4	4.4	2.9	4.1	1.9	1.0	2.7	3.3	1.0
Soda	13.7	6.0	11.7	10.7	10.9	56.1	7.1	6.6	24.6	6.1	5.6
Oxide of iron	2.6	5.7	4.4	2.7	8.1	5.1	4.0	3.4	3.6	3.7	3.7
Chlorine	20.7	10.7	11.1	20.7	26.1	12.0	32.0	31.6	30.9	36.6	39.4
Sulphuric acid	106.1	24.7	66.3	73.3	90.1	41.0	44.4	54.3	96.7	86.9	99.7
Phosphoric acid	..	0.63	0.91	1.54	0.91	—	1.44	1.66	1.26	1.09	1.01
Carbonic acid	43.3	48.1	44.4	59.0	58.0	73.0	45.4	44.9	64.6	51.1	56.9
Silica	35.7	10.9	15.4	24.7	17.0	10.6	10.9	11.3	17.9	28.3	14.0
Total solids	476.1	246.4	326.0	407.6	492.4	423.9	406.9	425.9	530.9	544.3	598.6

the available supply of nitrogen as fast as it is formed so that there is no appreciable excess to be carried away.

It has been found that about 37 pounds of nitrogen per acre are lost from average idle land during a year. This loss of nitrogen is quite large when we consider the amounts removed by our farm crops.[12]

	Pounds of nitrogen removed per acre
Wheat, 20 bushels	25
Straw, 2,000 pounds	10
Total	35
Barley, 40 bushels	28
Straw, 3,000 pounds	12
Total	40
Oats, 50 bushels	35
Straw, 3,000 pounds	15
Total	50
Flax, 15 bushels	39
Straw, 1,800 pounds	15
Total	54
Corn, 65 bushels	40
Stalks, 3,000 pounds	35
Total	75
Potatoes, 150 bushels	40

Fallowing.—In the arid sections of this country where dry farming is followed it is often necessary to let the land remain idle for a season to conserve enough moisture to produce profitable crops. The land is usually plowed two or three times, at intervals, or plowed once and harrowed two or three times. This procedure keeps down the weeds and increases the moisture in the soil. According to King, 203 tons more water was found on fallowed land per acre in the spring following the fallow, than on land that was not fallowed, and 179 tons more water was found on the fallowed field after a crop was harvested than on the other field.[17]

Fallowing increases the supply of available nitrogen as nitrates and in some sections fallowing is practiced for this reason. The yield of the crop following fallowing is increased but considerable humus is lost by being oxidized, and generally more nitrates are formed than can be used up by the crop following fallowing. Snyder has found by experiments that 590 pounds of nitrogen per acre were lost by two years of summer fallowing, or an amount sufficient for five wheat crops.[18] At the Rothamstead Experiment Station experiments show that considerable more nitrogen was lost from bare soils than from wheat land.[19]

NITROGEN IN DRAINAGE WATERS AVERAGE OF 12 YEARS (OR MORE).

Month	Rainfall (inches)	Bare soil, 60-inch gauge			Wheat land, nitrogen (per million of water)
		Drainage (inches)	Nitrogen (per million of water)	Nitrogen (pounds per acre)	
January	2.13	1.93	8.9	3.88	3.1
February	2.16	1.74	9.1	3.57	4.0
March	1.70	0.94	8.9	1.89	2.0
April	2.25	0.79	9.0	1.61	1.9
May	2.48	0.79	9.1	1.63	0.9
June	2.59	0.78	9.1	1.60	0.1
July	2.85	0.62	11.8	1.66	0.1
August	2.69	0.76	13.3	2.28	0.1
September	2.70	0.82	13.4	2.50	3.9
October	3.12	1.68	11.9	4.53	4.6
November	3.20	2.32	11.4	5 98	3.6
December	2.34	1.88	10.6	4.51	4.8
January-April	8.24	5.40	9.0	10.95	2.8
May-August	10.61	2.95	10.6	7.17	0.3
September-December	11.36	6.70	11.8	17.52	4.2
January-December	30.21	15.05	10.5	35.64	2.4

The loss of nitrogen from the bare uncropped soil reached 10.6 parts per million from May to August while that of the soil on which wheat was grown amounted to 0.3 pounds per million of water for the same period. After the wheat was harvested the loss of nitrogen increased.

On rich soils the losses are greater than on soils deficient in organic matter because the oxidation of organic matter is more

rapid. It is evident, then, that fallowing increases the production of crops at the expense of a reduction of organic matter.

In sections of plentiful rainfall, fallowing is often injurious and it should only be practiced in the dry sections where there is not enough rainfall to carry away the nitrates and therefore not sufficient moisture for the continuous growing of crops.

Other Ways Nitrogen is Lost.—The washing away of nitrogen as nitrates is not the only way this element is lost, but considerable of this valuable constituent escapes in the form of gases. This loss as gas is occasioned by dentrification, which reduces the nitrates to gases, and to the liberation of nitrogen from organic matter. The loss on soils rich in organic matter is greater than on poor soils.

Experiments show that in continuous cropping more nitrogen is usually lost than the crop removes. The following table illustrates this point.[20]

LOSS OF NITROGEN BY CONTINUOUS CROPPING PER ACRE PER YEAR.

Name of crop	Nitrogen removed by crop Pounds	Nitrogen lost by other means Pounds	Total nitrogen removed and lost Pounds
Wheat	24.5	146.5	171
Corn	56	29	85
Oats	46	150	196
Barley	30	170	200

The loss of nitrogen by continuous cropping of cotton, corn, tobacco and the cereal crops is a very serious one.

Loss of Phosphoric Acid and Potash.—Although phosphoric acid and potash are usually present in the soil as compounds insoluble in water, nevertheless large quantities are lost every year by being carried away with the soil into rivers and other streams. Again, traces of phosphoric acid and potash are carried away in the soluble form by drainage and although this loss is not large per acre it amounts to a great deal in the course of time. The Mississippi River deposits in the Gulf of Mexico 3,702,758,400 cubic feet of solid material per year. One cubic foot of this solid material weighs about 80 pounds.

This material is quite rich in potash often containing as high as 0.50 per cent. of this constituent. The phosphoric acid content is much lower than this figure but it is considerable. The rivers that empty into the oceans in the northern part of the United States do not perhaps carry away so much fertility as the rivers of the far south, but the annual loss of the mineral elements carried away in streams is appalling.

One Crop Farming.—The exclusive growing of one crop caused more farms to be abandoned in the United States than any other practice. The continuous cropping of wheat in the West, tobacco in Kentucky, Virginia and North Carolina, cotton in the South, and corn in the North Central States has always resulted in the loss of fertility and depletion of the soil. All of these crops with the exception of corn are sold from the farm without the return of any fertility. On most of these one crop farms no fertility is put on the soil and the farm is abandoned or else artificial (commercial) fertilizers are used. Most of our soils in the United States were formerly fertile but the practice of growing crops without returning organic matter has resulted in decreasing the yields on our older cultivated lands. Under the subject "fallowing" we learned that it was poor procedure to allow the land to lie idle except in dry regions, and the best farmers to-day are those that utilize their land continually and to the fullest extent. When we visit some of the European countries where land has been in cultivation for centuries, we find that these lands are still producing valuable crops, and that the yields are as large, if not larger now, than they were two centuries ago. This condition exists in Europe because fertility has been returned to the soil every year to sustain crops.

Fortunately, land has been comparatively cheap in the United States and when a farm failed to produce paying crops another piece of land was secured, and so on. The time has arrived when the acquiring of new land for one crop farming is hard to obtain at a price within the bounds of such farmers. So it is now necessary and more profitable for the farmer to grow other crops in conjunction with his money crop. This growing of other crops is called diversifying or rotating.

Diversification and Rotation of Crops.—Diversification is the growing of different crops without any regular or definite system. Rotation of crops is spoken of as growing a certain number of crops, in regular order, on the same piece of land. For example, a rotation may consist of four crops, corn, oats, wheat and clover, and will be called a four year rotation because these crops will be grown in order on the same piece of land and take four years to complete. A farmer may have 160 acres in his rotation and each year 40 acres will be allowed for each of the four crops mentioned. Each 40 acres will grow the same crop every fifth year and one of the crops every year. The terms six-year, five-year, four-year, three-year, two-year, etc. are applied to rotations depending upon the time it takes to complete them. Rotations taking 15 years to complete are known in Europe but the short rotations of three to six years are found to be profitable in the United States.

Make up of a Rotation.—The crops used in rotations are natually selected according to the location, nature of the soil, available crops, market prices, kind of farming, insect and plant diseases, climate, etc. A stock farm would require different crops than a tobacco farm; a dairy farm in Wisconsin could not probably use the same rotation as a dairy farm in Alabama; two farms in the same state with different soil conditions would perhaps select different crops for a rotation; a farm ten miles from a market would no doubt find it more practical to grow different crops than one 1,000 miles away; and crops would not be chosen that insects or plant diseases ruin.

Reasons for Rotating Crops.—Some of the reasons for rotating crops are:

1. To keep down weeds.
2. To gather nitrogen from the air.
3. To distribute farm labor more evenly.
4. To eradicate insect or other diseases.
5. To furnish feed for live-stock.
6. To give the farmer a regular income.
7. To prevent losses of fertility.

8. To utilize plant food more evenly.
9. To include deep and shallow rooted plants.
10. To save fertilizer expenditure.
11. To regulate the humus supply.
12. To conserve moisture in dry sections.

1. **Rotation of Crops Keeps Down Weeds.**—It is well known that the growing of particular crops is accompanied by certain weeds. Those crops that are sown broadcast, as the small grains, are more apt to be weedy than cultivated crops as corn, cotton, tobacco, potatoes, etc. When crops like wheat, hay, etc. are grown continuously the yields or the quality of the crops are often materially reduced by weeds. Intertilled crops as corn, tobacco, cotton, potatoes, etc., when well cultivated, are known as "cleaning crops." So in planning a rotation crops should be selected that will tend to keep down weeds. Cultivated crops should be included with those that are sown broadcast.

2. **Legumes are Profitable.**—By including legumes as clovers, Canada field pea, cowpea, velvet bean, soy bean, etc. in a rotation, it is possible to gather considerable nitrogen, which is the most expensive fertilizing element to buy, from the air. A crop of red clover, one year old, is estimated to contain 20 to 30 pounds of nitrogen in the roots, per acre. A crop of cowpeas in Louisiana furnishes 100 pounds of nitrogen per acre. By plowing under leguminous crops enough nitrogen is often furnished so that the following crop does not require any extra supply, and of some nitrogen has to be supplied, that amount is much less than it would be were not nitrogen gathering crops utilized.

The Minnesota Experiment Station[21] found a loss of 2,000 pounds of nitrogen per acre when wheat, barley, corn and oats were grown for twelve consecutive years; two-thirds to three-fourths of this amount was not used by the crops but was lost in other ways. The Ohio Experiment Station[22] found that there was a gain of 300 pounds of nitrogen per acre in excess of what the crop utilized when clover was included in five-year rota-

tions, covering periods of ten years. When timothy and non-legumes were used in place of clover, nitrogen was lost from the soil; the loss of nitrogen from the soil was a little more than that removed by the crop.

3. **The Distribution of Farm Labor.**—One of the most important points in favor of a rotation of crops is that it allows of a more even distribution of farm labor. When several crops are grown every year the farmer is able to employ help the greater part of the year and thus secure more efficient labor at a less cost for the work performed than should single crop farming be in vogue.

4. **The Checking or Eradication of Insects and Plant Diseases.** Many times crops became so badly attacked by insects, or infested with plant diseases, that there are no profits and often large losses in trying to produce them, on the same field continually. A rotation of crops often eliminates such troubles because certain insects and plant diseases are only common to one particular crop. A good illustration of this is noticeable in the growing of cotton. There is an insect called the cotton boll weevil, which punctures cotton bolls and destroys the crop. Fields that once produced valuable crops of cotton must now be planted to other crops which are not injured by this insect.

5. **Rotation Furnishes Feed for Live-Stock.**—One crop farmers are often forced to buy feed for their live-stock. A farmer who uses a rotation of crops can plan his rotation so that most of the feed will always be produced on the farm. In one crop farming the sale of the crop brings only one value. When several crops are grown it is possible to produce feed for live-stock and a double value is received for the crop. This double value is represented in the feeding value and fertilizing value, the crop is fed and the manure spread on the land.

6. **A Regular Income.**—Farmers who raise single crops receive their money but once a year and many of these farmers use their crops in paying the merchant for the last year's supplies. They often live from year to year on the credit basis and pay much more for their supplies than the farmer who is able to pay for

what he gets in cash. In certain sections of this country this credit system of farming has proved disastrous because one or two bad years caused the loss of the farm. The single crop farmer generally has to buy more supplies than the farmer who grows several crops. The farmer who practices rotation has crops to sell at different times in the year and so has a more regular income than the single crop farmer who gets his money but once a year.

7. **Preventing Losses of Fertility.**—The farmer who rotates his crops may sell the crop that removes the least fertility from the soil and if the money crops remove a great deal of fertility, he may regulate his rotation so as to restore this loss cheaply.

8. **A rotation of crops utilizes plant food more evenly** than when single crops are continually grown. Corn, wheat and other grain crops use a great deal of nitrogen and phosphoric acid while tobacco and potatoes are heavy potash feeders. By the proper selection of crops forming a rotation, the plant food may be drawn on more evenly and losses of fertility prevented through leaching, etc.

9. **Deep and Shallow Rooted Plants.**—A rotation of crops has an advantage over single crop farming because of the variation in depth of root systems of different crops. Alfalfa and corn have deep tap roots and obtain food from the subsoil, while oats, timothy, blue grass, rye, etc. have shallow roots and feed from the upper soil. By alternating deep and shallow rooted plants the fertility from the subsoil and surface soil is more evenly utilized. Often the surface soil may predominate in nitrogen and phosphoric acid and the subsoil in potash and lime. When the fertility is thus distributed the alternating of shallow and deep rooted plants is important as the fertility of the subsoil is brought to the surface soil by the decay of roots.

Another advantage of growing deep and shallow rooted plants is the improvement of the physical condition of the soil. Deep rooted plants tend to make a soil more porous because the decay of roots leaves passages in the soil which aid in draining and aerating it. Grass crops tend to make a soil compact, while

alfalfa, roots, grains and other cultivated crops tend to open up the soil.

A rotation should be selected to keep the soil in good physical condition. Sandy soils are improved by crops that compact them while clay soils should be made more porous.

10. **Rotation Saves Fertilizer Expenditure.**—On some farms that formerly used 150 to 300 pounds of commercial fertilizer per acre, as high as 1,500 to 2,000 pounds must be used now to give the same yields. A proper rotation of crops will save the employment of such large quantities of commercial fertilizers. Farm manure may be used, and commercial fertilizer only applied to those crops that are most in need of nourishment.

11. **Rotation of Crops Regulates the Humus Supply.**—Some crops furnish humus while others tend to deplete the soil of this material. Single crop farming is very exhaustive on the humus supply of the soil while a rotation of crops should be selected to conserve the humus content of a soil. Grass crops tend to increase the humus supply, while grain, cotton, tobacco, etc. have the opposite effect of consuming humus. The addition of farm manure is helpful in supplying humus. The following table shows the effect of a rotation of crops on the humus supply.[23]

	Weight per cu. ft. Pounds	Humus Per cent.	Nitrogen Per cent.	Phosphoric acid combined with humus Per cent.	Water holding capacity Per cent.
1. Cultivated 35 years; rotation of crops and manure; high state of productiveness	70	3.32	0.30	0.04	48
2. Originally same as 1; continuous grain cropping for 35 years; low state of productiveness	72	1.80	0.16	0.01	39
3. Cultivated 42 years; systematic rotation and manure; good state of productiveness	70	3.46	0.26	0.03	59
4. Originally same as 3; cultivated 35 years; no systematic rotation or manure; medium state of productiveness	67	2.45	0.21	0.03	57

Crop Rotations.

Locality and nature of farming	1st year	2d year	3d year	4th year	5th year	6th year
New England States (general farming)	Corn	Oats	Wheat	Mixed timothy and clover		. .
North Central States	Corn	Oats	Mammoth red clover and timothy		. .	. .
Virginia and neighboring states (general farming) . .	Corn; seeded to wheat and mixture of clover and timothy	Wheat	Hay	Hay or pasture	. .	. .
Potato (Irish) sections	Potatoes	Wheat or oats	Timothy and clover (mixed)	. .	. .	. .
Cotton sections	Corn; cowpeas at last cultivation	Oats or wheat; followed by cowpeas	Cotton	. .	. .	. .
Tobacco sections	Tobacco	Wheat	Clover hay or plowed under	. .	. .	. .
Alfalfa sections	Alfalfa 4 years; corn 2 years; small grain 1 or 2 years				. .	. .
Alfalfa sections (4 years) . .	Corn	Wheat	Alfalfa	Alfalfa	. .	. .
Alfalfa sections (6 years) . .	Corn	Corn	Alfalfa and barley	Alfalfa	Alfalfa	Alfalfa
Corn sections	Corn	Corn	Oats or wheat	Clover and timothy (mixed)	. .	. .
Sugar-cane section	Plant cane	1st year stubble	Corn; cowpeas at last cultivation	. .	. .	. .
Small grains or hay sections .	Wheat or rye 1 year	Clover or clover and grass 3 to 6 years			. .	. .
Live-stock Farms; Va., N. C., S. C., and adjoining Western States	Corn; seeded to crimson clover	Clover cut for hay or plowed under; followed by cowpeas for hay; seeded to small grain	Small grain; wheat, oats or rye; seeded to clover and grass	Hay	Hay or pasture	. .
Dairy farms, New Jersey . .	Corn; seeded to crimson clover	Crimson clover followed by fodder corn; seeded to winter rye	Rye fodder; followed by oats and peas; seeded to red clover and timothy	Hay	. .	. .
Dairy farm	Potatoes	Corn	Corn for silage	Grass and clover	Grass and clover	. .
Hog farm (Illinois)	Corn $^{4}/_{5}$; soy bean $^{1}/_{5}$	Corn	Oats	Clover	. .	. .

In the wheat sections of the West, wheat is grown for one or two years and the land allowed to summer follow every other or third season.

Approximate Maximum Amounts Removable Per Acre Annually

Produce		Pounds			Market value			
Kind	Amount	Nitrogen	Phosphorus[1]	Potassium[2]	Nitrogen	Phosphorus	Potassium	Total value
Corn, grain	100 bush..	100	17	19	$15.00	$ 0.51	$ 1.14	$16.65
Corn, stover.....	3 tons.....	48	06	52	7.20	0.18	3.12	10.50
Corn crop[3]		148	23	71	22.20	0.69	4.26	27.15
Oats, grain......	100 bush..	66	11	16	9.90	0.33	0.96	11.19
Oat straw	2½ tons...	31	05	52	4.65	0.15	3.12	7.92
Oat crop		97	16	68	14.55	0.48	4.08	19.11
Wheat, grain....	50 bush....	71	12	13	10.65	0.36	0.78	11.79
Wheat straw	2½ tons...	25	04	45	3.75	0.12	2.70	6.57
Wheat crop ...		96	16	58	14.40	0.48	3.48	18.36
Soy beans.......	25 bush...	80	13	24	12.00	0.39	1.44	13.83
Soy bean straw ..	2¼ tons...	79	08	49	11.85	0.24	2.94	15.03
Soy bean crop.		159	21	73	23.85	0.63	4.38	28.86
Timothy hay....	3 tons.....	72	09	71	10.80	0.27	4.26	15.33
Clover seed.....	4 bush....	07	02	03	1.05	0.06	0.18	1.29
Clover hay	4 tons.....	160	20	120	24.00	0.60	7.20	31.80
Cowpea hay.....	3 tons.....	130	14	98	19.50	0.42	5.88	25.80
Alfalfa hay......	8 tons.....	400	36	192	60.00	1.08	11.52	72.60
Cotton lint......	1,000 lbs..	03	0.4	04	0.45	0.01	0.24	0.70
Cotton-seed	2,000 lbs..	63	11	19	9.45	0.33	1.14	10.92
Cotton stalks....	4,000 lbs..	102	18	59	15.30	0.54	3.54	19.38
Cotton crop ...		168	29.4	82	25.20	0.88	4.92	31.00
Potatoes	300 bush..	63	13	90	9.45	0.39	5.40	15.23
Sugar-beets......	20 tons....	100	18	157	15.00	0.54	9.42	24.96
Apples	600 bush..	47	05	57	7.05	0.15	3.42	10.62
Leaves	4 tons.....	59	07	47	8.85	0.21	2.82	11.88
Wood growth ...	1/50 tree....	06	02	05	0.90	0.06	0.30	1.26
Total crop.....		112	14	109	16.80	0.42	6.54	23.76
Fat cattle	1,000 lbs...	25	07	01	3.75	0.21	0.06	4.02
Fat hogs	1,000 lbs...	18	03	01	2.70	0.09	0.06	2.85
Milk............	10,000 lbs..	57	07	12	8.55	0.21	0.72	9.48
Butter....	400 lbs....	0.8	0.2	0.1	0.12	0.01	0.01	0.14

[1] To change phosphorus to phosphoric acid, multiply by 2.29.
[2] To change potassium to potash, multiply by 1.204.
[3] To this might be added 1,000 pounds of corn cobs, containing 2 pounds of nitrogen, less than ½ pound of phosphorus, and 2 pounds of potassium.

12. **Rotation of Crops Conserves Moisture.**—In the arid regions the conservation of moisture is an important consideration in planning a rotation. Heavy moisture consuming crops should not be planted in succession in sections of small rainfall, but heavy consuming and light consuming moisture crops should be so grown as to conserve the moisture supply.

Crop Rotations.—On page 47 are a few examples of crop rotations practiced in different sections of the United States. These have been secured from various sources.

System of Farming.—The loss of fertility sold from the farm every year depends upon the kinds of crops produced and sold. The table on page 48 gives the fertility removed by farm produce.[19]

Note the small amount of fertility lost when live-stock are sold and also when butter and milk are marketed. The legumes and root crops remove a great deal of potash.

When crops are fed to live-stock and the manure produced put on the land there is not a great loss of fertility, but when crops like the cereals are sold there is no saving of fertility.

LOSS BY EXCLUSIVE GRAIN FARMING.[18]

Sold from the farm	Nitrogen Pounds	Phosphoric acid Pounds	Potash Pounds
Flax, 40 acres	1,600	600	800
Flax straw	600	120	320
Wheat, 50 acres	1,250	625	350
Wheat straw	500	375	1,400
Oats, 20 acres	700	240	200
Oat straw	300	120	700
Barley, 50 acres	1,400	750	400
Barley straw	600	250	1,500
Total	6,950	3,080	5.670

On this farm of 160 acres the loss of nitrogen is practically four times the amount (6,950) because in this system of farming four times more nitrogen is lost by natural means than is removed by the crop. This will total the loss in this farm to 27,800 pounds of nitrogen, 3,080 pounds of phosphoric acid and 5,670 pounds of potash. On this farm the straw is burned and the ashes thrown away and no live-stock are kept.

On another farm of the same acreage where live-stock are kept, manure saved, several crops grown, and rotation practiced, the following are the losses:[18]

STOCK FARMING.

Sold from the farm	Nitrogen Pounds	Phosphoric acid Pounds	Potash Pounds
Butter, 5,000 pounds	5	5	5
Young cattle, 10 head	200	190	16
Hogs, 20 of 250 pounds each	100	40	10
Steers, 2	48	38	4
Wheat, 10 acres	250	125	70
Flax, 10 acres	390	150	190
Rye, 10 acres	285	128	85
Total	1,278	676	380
Raised and consumed on the farm			
Clover, 20 tons	00	270	600
Timothy, 20 tons	600	180	800
Corn, 20 acres	1,500	300	800
Corn fodder, 1 acre	75	15	60
Mangels, 2 acres	150	70	300
Potatoes, 1 acre	40	20	75
Straw, 40 tons	400	200	1,000
Peas, 5 acres	000	85	200
Oats, 20 acres	700	240	200
Barley, 20 acres with straw	800	400	760
Total	4,265	1,780	4,795
Mechanical loss of food consumed, 3 per cent	128	53	144
Feed and fuel purchased			
Bran, 5 tons	275	260	150
Shorts, 5 tons	250	150	100
Oil meal, 1 ton	100	35	25
Hard-wood ashes	—	25	100
Total	625	470	375
Mechanical loss in material purchased, 3 per cent	19	14	10
Sold from farm	1,278	676	380
Loss in feed consumed	128	53	144
Total	1,425	743	534
Feed and fuel purchased	625	470	375
Balance lost from farm	800	273	159

There is much less loss in the second system of farming than the first. The amounts of phosphoric acid and potash lost are very small and the loss of nitrogen is compensated for by that left in the soil by the legumes, peas and clover.

From the foregoing data it is evident that the system of farming determines the loss of fertility.

CHAPTER IV.

FARM MANURES.

Farm manure has been used for centuries in restoring fertility to the soil. It is the oldest and one of the most important of our fertilizers. It is formed from vegetable and animal substances and naturally should prove of great value. In some sections of this country farm manure is wasted, but the value of this material is generally becoming better understood and is more carefully saved than formerly, especially in the older farming regions.

Kinds of Manure.—When there is a great deal of straw or hay in manure, it is said to be coarse. It is termed stable manure when it is accumulated in stables and contains all the solid and liquid portions. Barnyard manure is a name applied to manure which is subject to exposure of rains and sun and may be composed of pure solid excrement, or excrement and bedding.

Conditions Affecting the Value of Manure.—There are many conditions which affect the value of manure.

1. The age of the animal.
2. The use of the animal.
3. The kind and amount of bedding used.
4. The kind of animal.
5. The nature and amount of feed used.
6. The care, preservation and use of the manure.

1. **The age of the animal** influences the value of manure. Manure from young animals is not so rich in the fertilizer constituents, nitrogen, phosphoric acid and potash as that from mature animals, even when the same kind of feed is used. Young animals require and retain nitrogen and phosphoric acid for growth, while mature animals use these constituents for maintaining the functions of the body and for repairing broken down tissues, after which they are cast off in the manure.

2. **The use of the animal** influences the value of manure Lawes' and Gilbert's experiments along this line show:[13]

	Nitrogen		Mineral matter	
	Contained in product Per cent.	Contained in excrement Per cent.	Contained in product Per cent,	Contained in excrement Per cent,
Horse at rest	None	100.0	None	100.0
Horse at work	None	100.0	None	100.0
Milking cows	24.5	75.0	10.3	89.7
Fattening oxen	3.9	96.1	2.3	97.7
Fattening pigs	14.7	85.3	4.0	96.0
Fattening sheep	4.3	95.7	3.8	96.2

Hall shows the nitrogen retained and digested by fattening oxen and milch cows. This table is calculated on feeding 100 pounds of linseed cake.[9]

	In 100 lbs. linseed cake	Fattening oxen			Milch cows		
		In meat	In urine	In faeces	In milk	In urine	In faeces
Nitrogen	4.75	0.21	3.88	0.66	1.32	2.75	0.66
Phosphoric acid.	2.00	0.14	0.09	1.77	0.50	0.07	1.43
Potash	1.40	0.02	1.10	0.28	0.14	1.05	0.21

It is shown that milch cows return less of the fertilizing con-

Fig. 4.—Milch cows return less fertility from feeds than other farm animals.

stituents in the feed than other domestic farm animals. Fattening pigs return less than fattening sheep and fattening sheep less than fattening oxen. Horses return the same relative amounts from the feed whether at work or at rest.

3. **The Kind and Amount of Bedding Used.**—Bedding besides affecting the value of manure renders stables more sanitary. It provides comfort for the animal, makes the manure lighter and easier to handle, absorbs the liquids, lessens fermentation and improves the texture of the manure.

Straw is the most common bedding used and is well suited for this purpose, because it is largely made up of cellulose which is a good absorber, and on account of its hollow structure. The following table gives the composition of some of the principal straws.

Kind	Water Per cent.	Ash Per cent.	Organic matter Per cent.	Nitrogen Per cent.	Phosphoric acid Per cent.	Potash Per cent.
Wheat straw	9.6	4.2	86.2	0.59	0.12	0.51
Oat straw	9.2	5.1	85.7	0.62	0.20	1.04
Rye straw.......	7.1	3.2	89.7	0.46	0.28	0.79
Barley straw	14.2	5.7	80.1	0.70	0.30	0.80

From the above it is shown that there is a difference in the composition of straws, but they all contain a high potash content. The nitrogen and phosphoric acid are rather low and when large amounts of straw are employed the fertilizing value of the manure is naturally lowered.

Leaves.—Dried autumn leaves are often gathered and used as bedding. They are not as valuable as straw as they do not ferment very rapidly and are liable to cause acidity in the manure.

COMPOSITION OF DRIED LEAVES.

	Per cent.
Nitrogen	0.65
Phosphoric acid........................	0.15
Potash	0.30

Sawdust is often used as bedding and it is much inferior to straw and dried leaves from a fertility standpoint. It decomposes very slowly in the soil. However this material is a good

absorber of the liquid portions and makes a good bedding when it can be obtained cheaply.

Composition of Sawdust.[18]

	Per cent.
Nitrogen	0.1
Phosphoric acid	0.2
Potash	0.4

Shavings are sometimes used as bedding and possess about the same properties as sawdust.

Peat when dried is a good material to use in stables as it is an excellent absorber. It absorbs not only the liquid portions of the manure but also the nitrogen gases evolved, and renders the stable free from foul odor. It in itself contains considerable organic matter which is beneficial and it is readily fermented in the soil. It is a good material to use in conjunction with straw. The use of peat as bedding increases the nitrogen content of the manure. The nitrogen percentage in peat varies a great deal but it usually approximates 1 to 1.5 per cent.

Absorptive Power of Bedding.—According to Snyder,[18] the absorptive power of different kinds of bedding are:

	Per cent. of water absorbed
Fine cut straw	30-0
Coarse uncut straw	18.0
Peat	60.0
Sawdust	45.0

Snyder[18] says: "The proportion of absorbents in manure ranges from a fifth to a third of the total weight of the manure."

The following experiment shows the absorptive power of straw and peat in two similar stables carrying the same stock, in one of which straw was used and the other peat.

Ammonia In Stable Per Million of Air.[9]

Litter	1st day	2d day	3d day	4th day	5th day	6th day	7th day
Straw	0.0012	0.0028	0.0045	0.0081	0.0153	0.0168	—
Peat moss	—	—	—	—	trace	0.001	0.017

4. **The Kind of Manure.**—Manure from different kinds of animals varies in value.

Horse Manure.—The manure voided by the horse is rich in nitrogen and not so finely divided as the manure from cows, sheep, etc. This is due to the horse only having one compartment in its stomach and therefore the feed, especially coarse feed as hay, etc., is less broken up and digested. Horse manure is generally comparatively dry and hard to incorporate with bedding. On this account, and because of its coarse nature and chemical composition, fermentation readily sets in and considerable nitrogen is lost unless the fermentation is stopped. When fermentation is allowed to continue the value of horse manure is very much decreased. Boussingault found by experiment that when fermentation was allowed to continue, one-half of the nitrogen was lost from the fresh manure.

The amount of manure produced by a horse per year is:[25]

	Pounds
Solids	12,000
Liquids	3,000

Boussingault and Hofmeister found, on the average, that 28.11 pounds of manure was produced daily by the horse. Heiden estimates that 4 to 6 pounds of straw should be used daily to absorb horse manure. Estimating the amount of straw at 5 pounds, the total weight of manure would approximate 6 tons for a year, or[24]

	Pounds
Solids	9,600
Liquids	2,400

The above experiments show that a horse produces about 6 to 7.5 tons of manure per year in the stable, of which three-fourths are solids and one-fourth liquids.

COMPOSITION OF HORSE MANURE.[18]

Water		Nitrogen		Phosphoric acid		Potash
Solids Per cent.	Liquids Per cent.	Solids Per cent.	Liquids. Per cent.	Solids Per cent.	Liquids Per cent.	Solids Per cent.
84	92	0.30	0.86	0.25	——	0.10

The liquid portion of horse manure contains a great deal more

nitrogen that the solid. The liquid portion of horse manure contains very little phosphoric acid.

Cow manure is much colder than horse manure and so a fine combination results when it is mixed with horse manure; the fermention of the horse manure is stopped and the nitrogen saved, and the mixture is better than cow manure alone. Cow manure contains more water than horse manure due perhaps to the large amounts of water drank by this class of animal. Cow manure does not ferment rapidly and when dry decomposes very slowly in the soil. It is estimated that 6 to 10 pounds of straw are necessary to absorb cow manure, depending upon the amount of liquids voided.

The amount of manure produced by a cow per year is:[25]

	Pounds
Solids	20,000
Liquids	8,000

Boussingault[24] found that 73.23 pounds of manure was produced by a cow per day. Of this amount about 25 pounds represents the liquid portion. With bedding, the amount of manure produced per day would approximate 80 pounds.

COMPOSITION OF COW MANURE.[18]

Water		Nitrogen		Phosphoric acid		Potash
Solids Per cent.	Liquids Per cent.	Solids Per cent.	Liquids Per cent.	Solids Per cent.	Liquids Per cent.	Solids Per cent.
76	89	0.50	1.2	0.35	——	0.30

The nitrogen content is present in greater amount in the liquids while there is little phosphoric acid present in this portion of cow manure.

Hog Manure.—The composition of hog manure is quite variable depending upon the feed consumed. When tankage and other highly nitrogenous feeds are employed the manure is rich, but when feeds containing small amounts of fertilizing constituents are used, the manure is not so valuable. Hog manure contains a high percentage of water and is slow to decompose. It is es-

timated that 4 to 8 pounds of straw are adequate for absorbing pig manure.

The amount of manure produced by the hog per year is:[25]

	Pounds
Solids	1,800
Liquids	1,200

Note the proportionately high liquid content of hog manure.

Boussingault found by experiments that a hog produced 8.32 pounds of manure per day.

Composition of Hog Manure.[18]

Water		Nitrogen		Phosphoric acid		Potash
Solids Per cent.	Liquids Per cent.	Solids Per cent.	Liquids Per cent.	Solids Per cent.	Liquids Per cent.	Solids Per cent.
80	97	0.60	0.80	0.45	0.12	0.50

The liquid portion of hog manure contains more phosphoric acid and the solids more potash than horse or cow manure. As previously mentioned, the nitrogen content of the liquid portion of hog manure depends upon the nature of the feed. Sometimes the nitrogen will reach 1.5 per cent. in the liquid portion. The liquid portion is higher in water than manure from other farm live-stock.

Sheep Manure.—The manure from sheep is more valuable than that from other farm animals. On account of its being dry and rich in nitrogen it ferments rapidly although not so quickly as horse manure. The slower action is perhaps due to its more compact mechanical condition. Losses of nitrogen in sheep manure are apt to occur unless the manure is well taken care of. To absorb the liquid portion 3/5 of a pound of straw per day is sufficient per sheep.

The amount of manure produced by a sheep per year is:[25]

	Pounds
Solids	760
Liquids	380

Heiden found that the average manure produced daily by sheep to be 3.78 pounds.

COMPOSITION OF SHEEP MANURE.[18]

Water		Nitrogen		Phosphoric acid		Potash
Solids Per cent.	Liquids Per cent.	Solids Per cent.	Liquids Per cent	Solids Per cent.	Liquids Per cent.	Solids Per cent.
58	86.5	0.75	1.4	0.60	0.05	0.30

Both the solids and liquids of sheep manure run higher in nitrogen than the manure from other farm animals, and the water content is lower. The phosphoric acid content of the solids is also high and that of the liquids appreciable.

Hen manure contains its nitrogen in a quickly available form and unless carefully preserved, fermentation sets in and drives off considerable of this valuable constituent as ammonia. Lime should not be used where the manure is kept as it hastens the liberation of ammonia. The per cent. of nitrogen in hen manure depends a great deal on the kind of feed consumed. Hens produce, per 1,000 pounds live weight, about 35 pounds of manure per day, and about one bushel of manure is produced by a hen per year.

COMPOSITION OF HEN MANURE.

	Per cent.
Moisture	57.00
Nitrogen	1.3
Phosphoric acid	0.85
Potash	0.30

It is shown that hen manure approximates sheep manure in composition. It is a valuable manure because it acts quickly.

COMPOSITION OF FOWL MANURE.[24]

	Fowls Per cent.	Pigeons Per cent.	Ducks Per cent.	Geese Per cent.
Water	56.00	52.00	56.60	77.10
Organic matter	25.50	31.00	26.20	13.40
Nitrogen	1.60	1.75	1.00	0.55
Phosphoric acid	1.5-2.00	1.5-2.00	1.40	0.54
Potash	0.80-.90	1.0-1.25	0.62	0.95
Lime	2.0-2.50	1.5-2.00	1.70	0.84
Magnesia	0.75	0.50	0.35	0.20

A pigeon yields about 6 pounds of manure per year, a turkey or goose about 25 pounds, and a duck 18 pounds.

ANALYSES OF BAT MANURE.[26]

Source	Insoluble phosphoric acid Per cent.	Total phosphoric acid Per cent.	Available phosphoric acid Per cent.	Nitrogen Per cent.	Potash Per cent.
Texas	0.10	2.65	2.55	8.64	2.59
Texas	0.12	2.98	2.86	8.65	1.80
Texas	0.13	2.43	2.30	5.81	1.71
Mexico	0.24	4.73	4.49	8.76	3.34

AVERAGE OF NINE ANALYSES FROM VARIOUS EXPERIMENT STATIONS.[17]

	Per cent.
Total phosphoric acid	5.95
Nitrogen	8.50
Potash	1.14

The following analyses of manures may prove interesting.

ANALYSES OF FARM MANURES.[11]

Kind of manure	Water Per cent.	Nitrogen Per cent.	Potash Per cent.	Phosphoric acid Per cent.
Cattle (solid fresh excrement)	—	0.29	0.10	0.17
Cattle (fresh urine)	—	0.58	0.49	—
Hen manure (fresh)	—	1.63	0.85	1.54
Horse (solid fresh excrement)	—	0.44	0.35	0.17
Horse (fresh urine)	—	1.55	1.50	—
Sheep (solid fresh excrement)	—	0.55	0.15	0.31
Sheep (fresh urine)	—	1.95	2.26	0.01
Stable manure (mixed)	73.27	0.50	0.60	0.30
Swine (solid fresh excrement)	—	0.60	0.13	0.41
Swine (fresh urine)	—	0.43	0.83	0.07

How to Calculate the Amount of Manure Produced.—A method used for determining the amount of manure produced by animals is to multiply the amount of dry matter in the feed consumed by 3.8 for a cow, 2.1 for a horse and 1.8 for a sheep. A horse that consumes feed containing 25 pounds of dry matter per day would void $25 \times 2.1 = 52.5$ pounds of manure a day. Add to this the amount of bedding used and you will arrive at the total amount of manure. The dry matter of the principal feeds

found on the American market will be found in the Appendix.

5. **The nature and amount of feed used** affects the value of the manure. The richer the feed the higher the fertilizing value of the manure. Coarse feeds like hay, straw, etc., produce less valuable manure than concentrated feeds like linseed meal, gluten meal, cotton-seed meal, etc. For the fertilizing value of feeds refer to the Appendix.

Experiments were conducted at Rothamstead on the effect of the feed on the nitrogen content of the excrement, by feeding steers roots and hay and roots, hay and oil cake (a nitrogen concentrate). The results follow.[9]

COMPOSITION OF FARM MANURE IN PER CENT. FROM ROOTS AND HAY ONLY, OR FROM ROOTS AND HAY AND CAKE.

	Year	Dry Matter	Total Nitrogen	Nitrogen as Ammonia	Nitrogen as Amides	Insoluble Nitrogen	
Roots and hay only	1904	23.60	0.577	0.046	0.067	0.464	Mixed & stored
Cake fed	1904	24.03	0.716	0.079	0.096	0.541	"
Roots and hay only	1905	29.50	0.462	0.040	0.047	0.375	"
Cake fed	1905	31.30	0.698	0.182	0.055	0.461	"
Roots and hay only	1906	22.00	0.466	0.022	0.033	0.411	"
Cake fed	1906	24.30	0.690	0.097	0.049	0.544	"
Roots and hay only	1907	25.30	0.589	0.125	0.053	0.411	Not stored
Cake fed	1907	25.50	0.815	0.377	0.033	0.405	"

It is seen that when steers were fed oil cake the manure was richer in nitrogen, by about 40 per cent., than when fed roots and hay alone. The nitrogen produced in the manure of those steers that were cake fed shows a higher availability.

The manure produced in these experiments was applied to the soil with the following crop returns.[9]

CROP RETURNS FROM THE ABOVE MANURES.

	Year of Application	Second Year	Third Year
	Mean of 4	Mean of 4	Mean of 3
Unmanured plot	100	100	100
16 tons per acre root and hay manure.	132	131	112
16 tons per acre cake fed manure.....	183	137	118

The unmanured plot was taken as 100. The crops grown were turnips, barley, mangolds and wheat in rotation, and the manure was applied for one year. The availability of the nitrogen produced by feeding cake is evidenced by the yield of the first year when the manure was applied. The yields of the second and third years are not much more than from the root and hay manure.

Commercial Value of Manure.—The commercial value of manure only represents the value from the standpoint of its plant food constituents nitrogen, phosphoric acid and potash. The nitrogen is valued at 15 cents per pound, the phosphoric acid at 6 cents and the potash at 4½ cents. There is no litter in these manures.[13]

Kinds of Live-stock	Percentage Composition				Pounds ingredients per ton manure			Value per ton	Productoin per 1,000 pounds live weight	
	Water	Nitrogen	Phosphoric Acid	Potash	Nitrogen	Phosphoric Acid	Potash		Pounds per day	Value per year
Horses . .	48.70	0.49	0.26	0.48	9.00	5.20	9.60	$2.21	48.8	$27.74
Cows. . . .	75.25	0.43	0.29	0.44	8.60	5.80	8.80	2.02	74.1	29.27
Calves. . .	77.73	0.50	0.17	0.53	10.00	3.40	10.60	2.18	67.8	24.25
Swine . . .	74.13	0.84	0.39	0.32	16.80	7.80	6.40	3.29	83.6	60.88
Sheep . . .	59.52	0.77	. .	0.59	15.40	7.60	11.80	3.30	34.1	26.09

The table shows sheep manure to be the most valuable per ton and cow manure the least valuable. The commercial value ranges from $2.02 to $3.30 per ton. It must be remembered that these values do not represent the agricultural value (the power to produce crops) or the beneficial effect it produces on the soil.

Lasting Effect of Manure.—The lasting effect of manure is shown by the experiments conducted at Rothamstead. A plot of grass land received applications of 14 tons of manure per acre for 8 consecutive years and then the applications were discontinued. During the first year after the discontinuance of manure the yield was twice that of an unmanured plot. Since that time the yield on the manured plot has slowly decreased until at the end of 40 years the excess has been about 15 per cent. greater than the yield of the unmanured plot.

An experiment was conducted with barley. Three plots were employed. One plot received 14 tons of manure per acre since 1852, another received 14 tons of manure per acre for 20 years and then the applications were stopped, and the third has been unmanured since 1852. The following table gives the results of this experiment.[9]

TOTAL PRODUCE PER ACRE OF BARLEY PLOTS, SHOWING LASTING EFFECT OF MANURE.

	Manure every year, 1852 and since	Manure for 20 years, 1852-1871 Unmanured since	Unmanured continually	Relation to Produce of Plot 7-2, reckoned as 100		
Mean	Plot 7-2 lb.	Plot 7-1 lb.	Plot 1-0 lb.	Plot 7-2 lb.	Plot 7-1 lb.	Plot 1-0 lb.
1852-1871	5,933		2,454	100		41
1872			1,282			25
1873	5,202	4,870	1,570	100	94	24
1874	6,561	5,165	1,922	100	79	24
1875	7,943	5,675	1,448	100	71	25
1876	5,825	3,955	1,561	100	68	25
	6.166	4,010		100	65	
Mean						
1877-1881	6,167	3,305	1,528	100	54	25
1882-1886	6,546	3,494	1,529	100	53	23
1887-1891	5,334	2,664	1,379	100	50	26
1892-1896	6,477	3,101	1,508	100	48	23
1897-1901	5,349	2,251	1,141	100	42	21
1902-1906	6,223	2,485	1.301	100	40	21

The above experiment shows that the continuously manured plot has the largest yields but the plot that was manured for 20 years is still producing crops at least 40 per cent. greater than the unmanured plot.

The results as shown in these experiments would not be found to be so apparent in actual farming, as the soils that were used for these experiments were more exhausted than the farmer would use. However, the results are interesting as they show the almost permanent effect of farm manure on soils.

6. **The Care, Preservation and Use of Manure.**—From the foregoing pages it is very evident that the composition of manure and the amounts produced by different kinds of animals are exceedingly variable. It was also shown that a regular value for this product cannot be estimated from its chemical composition.

Waste of Manure.—In some sections of the United States farm manure is dumped into streams, burned, buried in holes in the ground, or allowed to remain in large piles in some uncultivated place. The soils in many of such sections are fertile enough to produce profitable crops but it seems very wasteful to throw away such valuable fertilizer.

Leaching.—When a manure heap is exposed to the washing of rain and the solutions allowed to wash away, the value of the manure is decreased. The soluble plant food elements are washed away together with more or less of the manure itself. Leaching is one of the most important subjects to consider in the care and preservation of manure because it is the source of one of the greatest losses in this valuable product. Roberts[17] shows the great losses that may occur by leaching. He experimented with horse manure by allowing it to remain in a loose pile out of doors exposed to the rain from March 30th to Sept. 30th. The rainfall averaged about 28 inches during this period.

The composition of the manure at the beginning and at the end of the experiment follow:

	April 25 Pounds	Sept. 30 Pounds	Loss Per cent.
Gross weight	4,000.00	1,730.00	57
Nitrogen	19.60	7.79	60
Phosphoric acid	14.80	7.79	47
Potash	36.00	8.65	76

An experiment was conducted with cow manure at the same time under the same conditions except that 300 pounds of gypsum were mixed with it.

	April 25 Pounds	Sept. 30 Pounds	Loss Per cent.
Gross weight	10,000.00	5,125.00	49
Nitrogen	47.00	28.00	41
Phosphoric acid	32.00	26.00	19
Potash	48.00	44.00	8

It is shown that the cow manure did not leach so readily as the horse manure. The gypsum no doubt held back some of the nitrogen but even without the use of gypsum the loss would be less than from horse manure because cow manure is more firm and compact. The greater loss from the horse manure may also have been due to its more rapid fermentation, thus releasing considerable nitrogen as ammonia gas.

Roberts[28] also experimented with a mixture of horse and cow manure and straw, which was compacted by trampling of cattle in a covered shed, and put in a galvanized iron pan with a perforated bottom, for six months. The losses were as follows:

	March 29 Pounds	Sept. 30 Pounds	Loss Per cent.
Gross weight	226.00	222.00	—
Nitrogen	1.04	1.01	3.2
Phosphoric acid	0.61	0.58	4.7
Potash	1.20	0.43	35.0

The results in this last table show considerably less loss than when manure was not mixed or not compacted. The decrease in loss of nitrogen is greatest in the mixed tramped manure and this is due to the fact that fermentation was checked by mixing and tramping and therefore there was less loss of nitrogen as ammonia gas.

Fermentations.—There are certain bacteria that produce fermentations in manure piles and liberate nitrogen as gas causing large losses in manure. These fermentations are brought about by two classes of organisms; aërobic bacteria and anaërobic bacteria.

1. The aërobic bacteria require oxygen to be active and the anaërobic bacteria are only active in the absence of oxygen. On the outside of manure heaps where air circulates, the aërobic

bacteria work while in the interior of the heaps where no air can penetrate the anaërobic fermentation takes place. The aërobic bacteria convert the nitrogen present in the organic matter of the manure, into ammonia, in which form it passes off into the atmosphere. Because of the great amount of carbon dioxide formed during the action some of the ammonia is converted into carbonate of ammonia which is also volatile.

2. The anaërobic bacteria convert ammonia salts to nitrogen. Some of these bacteria have the power of reducing nitrates to nitrites, and to ammonia. The anaërobic bacteria do not bring about such losses as the aërobic bacteria, so it is important to keep the manure heap well compacted to prevent the action of the aërobic organisms.

Keep the Manure Moist.—Dry manure ferments more readily than wet manure. To prevent active fermentation the manure heap should be kept moist. It is not necessary to add enough water to leach it. Water excludes the air and promotes anaërobic action which is beneficial.

Composition of the Gases Formed in Manure Heaps.—The following table is interesting as it shows the composition of the gases in manure heaps.[27]

Date 1899	Height of manure heap in meters[1]	Point at which samples were taken	°C Temperature	Carbon dioxide	Oxygen	Marsh gas	Hydrogen	Nitrogen
Aug. 22	2.00	middle	52	54.3	0.00	7.8	23.5	14.4
Aug. 23	2.00	middle	52	58.0	—	14.2	11.8	16.0
		top	71	50.0	—	17.4	3.1	29.5
Aug. 24	2.30	middle	67	68.0	—	23.9	7.4	0.7
		bottom	63	49.0	—	40.8	3.9	6.0
Aug. 26	2.30	bottom	60	51.0	—	46.6	2.4	0.0
		top	60	7.2	7.0	0.0	—	85.8
Aug. 30	2.50	middle	65	14.5	4.7	1.3	—	79.5
		bottom	60	50.8	0.0	49.2	—	0.0
		top	66	42.7	1.1	52.4	—	9.8
Sept. 20	2.50	middle	65	49.5	—	48.3	—	2.2
		bottom	52	47.8	—	51.2	—	1.0
		top	55	54.0	0.5	43.0	—	2.0
Oct. 4	2.50	middle	65	42.7	—	56.1	—	0.0
		bottom	40	48.3	—	51.7	—	0.0

[1] A meter is equal to 39.37 inches.

Sample of August 22d was taken when the manure heap was being formed and was too dry. Liquid manure was sprinkled over the manure on August 22d, after the sample was taken, which increased the fermentation as evidenced by the temperatures on August 24th. The evolution of hydrogen decreased during the process of fermentation and the marsh gas increased. By August 30th the manure heap was again too dry and the top and middle portions were full of air as is shown by the large amounts of nitrogen, presence of oxygen, and low content of carbon dioxide. Such a condition, with the high temperature favored a loss of nitrogen as ammonia gas. When samples of Sept. 20th and Oct. 4th were taken the manure heap was moist and compacted, and the results show an anaërobic fermentation as is evidenced by the absence of hydrogen gas and the presence of almost equal amounts of carbon dioxide and marsh gas.

The temperature in fermenting horse, sheep and poultry manure often goes higher than 150° Fahrenheit (65° Centigrade). The highest temperature is usually near the surface as the fermentation is most active there.

Composting manure is helpful in increasing the availability of the plant food. It also kills many weed seeds. There is less loss of plant food when the manure is applied to the soil fresh, than when allowed to rot. It is not generally convenient to haul the manure from the stable to the land as other work is of more importance, so that the manure has to be stored until the regular farm work becomes slack. When manure is composted it should be kept compact and moist and the heap should be shaped to shed water. A layer of earth on the top of the manure compost will tend to absorb some of the gases.

Voelcker[13] gives the following as the composition of fresh and rotted manure.

	Fresh Per cent.	Rotted Per cent.
Water	66.17	75.42
Soluble organic matter	2.48	3.71
Soluble organic nitrogen	0.15	0.30
Soluble inorganic matter	1.54	1.47
Insoluble organic matter	25.76	12.82
Insoluble inorganic matter	4.05	6.58

It is seen that manure that is composted contains the fertilizer elements in a more available form than in fresh manure.

The organic matter is decreased by allowing manure to rot. Snyder[18] says: "A ton of composted manure is obtained from 2,800 pounds of stable manure." There are of course some losses of nitrogen in composting manure, the extent of these losses depending upon the compactness and dryness of the manure.

The principal benefits derived from composting manure are: the improvement of the physical condition, and decomposition takes place in the manure that ordinarily would have to be performed in the soil.

Sometimes manure is composted with earth, sod, leaves and wastes from the farm.

Store Manure Under Cover.—Whenever manure is left out of doors exposed to the rain losses occur. Many farmers preserve manure in different ways. Some use covered yards where the stock are allowed to exercise and the manure is kept compact by the tramping of the animals. In this practice bedding should be used to absorb all of the liquids and to allow the animals to be comfortable. The site should be well drained and kept dry. The manure from sheep, hogs, young stock, etc., is often preserved in this way. Some farmers keep the manure in cellars under the stable. The fermentation of manure in the cellar of a stable is liable to produce foul odors and is especially objectionable in dairy barns. Another method of storing manure that is used in the older farming sections, especially in dairies, is to build covered cement pits just outside the barn and dump the manure from trucks. The liquid portions are drained to these pits by pipes. It may not always be possible for a farmer to build a covered cement pit but he can always afford to put a roof over the manure, for the cost of the shed will soon be returned in the increased value of the manure.

The following table, the work of Biernatski, shows the composition of uncovered and covered manure.

	Water Per cent.	Nitrogen Per cent.	Phosphoric acid Per cent.	Potash Per cent.
Uncovered manure	83.78	0.47	0.26	0.43
Covered manure....................	76.54	0.68	0.31	0.76

Preservatives.—In the destruction of the nitrogen present in organic matter in manure, the aërobic bacteria produce ammonia and some of this gas unites with the carbon dioxide evolved and forms ammonium carbonate, a volatile compound. By adding moist gypsum (land plaster) to manure, the ammonium carbonate is converted into ammonium sulphate, a compound that does not pass away in the atmosphere. This latter compound is soluble in water and when manure is exposed to the leaching of rains, it is useless to employ gypsum. Gypsum is perfectly safe to use because it does not injure the feet of animals. Lime is objectionable because it liberates ammonia. Kainit, superphosphate and ground rock phosphate are sometimes used with good success, as they absorb nitrogen. These preservatives may be scattered at the rate of about one pound to an animal. They may also be economically used in covered manure heaps. Hall[9] estimates that it will take about 100 pounds of gypsum per ton of manure to absorb the gases, as some of it is acted upon by the potassium carbonate in the urine.

Physical Effects of Manure.—Manure has a greater value than is represented by its chemical composition. It improves the physical condition of the soil by,

1. Producing a better moisture condition.
2. Producing a better texture.
3. Preventing mechanical losses by winds.
4. Benefiting grass land.

1. **Manure Produces a Better Moisture Condition.**—Manure when added to soils increases the water holding power of those soils because of its humus content. Humus absorbs water readily. A soil that has had manure added to it will resist drought better

than one where there is little or no humus. During a heavy rainfall the soil with humus will absorb a great deal more water and give it up more gradually than one without humus. This is shown in the following table.[9]

PERCENTAGES OF WATER IN UNMANURED AND MANURED SOILS.

Depth in inches	Wheat field		Barley field	
	Unmanured	Manured	Unmanured	Manured
0 to 9	16.0	19.3	17.0	20.7
8 to 18	19.8	17.0	22.5	17.7
18 to 27	23.3	18.4	22.1	18.3

The wheat field samples were taken in September a day after a rainfall of 0.262 inches, but no rain had fallen for nine days previous. The plots where the samples were taken were fallowed so that the drying effect of the crop did not effect the results. The samples from the barley plot were taken a little over two weeks after the wheat plot samples. Three days before the barley samples were taken there was a rainfall of 0.456 inches, previous to which time there were 15 days of dry weather. The results are calculated on the percentages of fine earth after the stones were removed. The manured soil of the wheat and barley plots shows that the surface soil contains more water than the subsoil. There is about 3.5 per cent. more water in the surface soil than in the subsoil, which approximates 30 tons per acre or about 0.3 inch of rain. The loss between what was retained in the surface soil and the rainfall is due to evaporation. The unmanured soils show that the water percolated through to the subsoil. There were drains below the center of the wheat plots at a depth of 30 inches. The drain below the manured plot rarely contained water except after exceedingly heavy rain, while the drain below the unmanured plot contained water much more frequently.

Effect of Manure During Dry Seasons.—Manure helps to conserve the moisture supply of soil during dry seasons. The following table is the work of the Rothamstead Experiment Station.

EFFECT OF FARM MANURE IN DRY AND WET SEASONS WITH WHEAT.[9]

Plot	Fertilizer	Rainfall in inches March to June		Growing Season		Yield		Average 51 years
		1879	1893	1879	1893	1879	1893	
		13	2.9	Wet and Cold	Dry and Hot	Bushels		Bushels
2	14 tons mannre....	......	......	......	......	16.00	34.25	35.7
7	Complete fertilizer.	......	......	......	......	16.25	20.25	32.9

The yield during the dry season of 1893 shows an excess of 14 bushels in favor of the manured plot, while the exceptionally wet year shows equal small yields from both plots. The small yield was due probably to the inactivity of the bacteria that make plant food available. For 51 years there has averaged a yield of about 3 bushels more on the manured plot than on the plot which received artificial fertilizer.

2. **Manure Improves the Texture of the Soil.**—Manure has a very beneficial effect on most soils in improving the texture. The addition of manure to sandy soils makes them more binding and increases their water holding capacity. Clay soils are made more porous by the addition of manure. Some soils may produce good crops during favorable seasons without much organic matter but when the season is bad it is almost impossible to get the soil in good mechanical condition for crops.

NUMBER OF MANGOLD PLANTS TAKING 100 AS THE POSSIBLE.[9]
Average of 7 Years, 1901-7.

Farm Manure, Minerals and Nitrate of Soda	Minerals and Nitrate of Soda	Minerals and Rape Cake
69	62	83

[9] Hall, Fertilizers and Manure.

The plot receiving rape cake, which was applied at the rate of 2,000 pounds per year, shows the best results, but rape cake like manure supplies a great deal of organic matter. A better stand was produced with farm manure than with the artificial fertilizer.

3. **Manure Prevents Mechanical Losses by Winds.**—The losses occasioned by heavy winds on certain soils are sometimes more than one would expect. Dry light soils devoid of organic matter are easily blown away by heavy winds. The addition of manure to such soils tends to keep them moist and prevents such loss.

4. **Manure Benefits Grass Land.**—Manure benefits grass land not only by supplying plant food and increasing the moisture holding capacity, but also in protecting this crop from the frosts of early spring, by the mulch produced. It is noticed that grass that has been manured in the fall has an earlier growth in the spring than such lands unmanured

Bacteriological Effects of Manure.—Manure when added to the soil aids the growth of bacteria that render plant food available. It also increases the number of these bacteria and supplies food for them, and fermentations are promoted that are very helpful in the production of crops.

Time to Apply Manure.—In order to get all the value from farm manure it is better to apply it while fresh than when rotted. Manure in rotting loses some of its fertility. The Ohio Experiment Station have conducted experiments with fresh manure and exposed yard manure with the following crop returns for ten years.

	Amount applied per acre in tons	Yield of corn per acre bushels	Yield of wheat per acre bushels	Yield of hay per acre lbs.
Exposed yard manure .	8	16.03	8.21	698
Fresh manure.........	8	22.24	9.73	1,280

The manure was applied to clover sod which was plowed under and followed by a three year rotation of corn, wheat and clover without the addition of any more manure. The yields favor the fresh manure with an increase of 6.21 bushels of corn, 1.52 bushels of wheat and 582 pounds of hay.

Sometimes it is not practicable to apply manure while fresh as some crops, especially the quick growing market garden crops,

require plant food that is available and so prefer rotted manure.

It is common in this country to apply fresh manure to grass land in the fall and turn it under in the spring. This practice is beneficial in that it supplies a great deal of organic matter for the succeeding crop. Corn is a crop that thrives on fresh manure and so it is well to apply manure in this condition to corn and follow this crop with one that prefers rotted manure.

Amount of Manure to Apply.—The amount of manure to apply depends upon the fertility and texture of the soil. Soils that already have considerable fertility sometimes require a light application of manure to improve their texture. Large applications of manure on such soils would not be profitable. Most farmers use too much manure on their land at one time. Frequent light applications are more beneficial than large amounts applied at long intervals, as they keep the soil in an even state of fertility and losses of volatilization of nitrogen as gases and leaching of the soluble elements are less. Experiments show that small applications give greater percentage increase than large applications, although large applications give larger yields.

Sometimes manure does not furnish sufficient plant food to satisfy the needs of the crop. An addition of some commercial fertilizer which supplies the necessary fertilizer constituents is beneficial in such cases to supplement the manure.

How to Apply Manure.—It is best to spread the manure over the land as it is hauled. Some farmers dump the manure in little piles over the field and leave it in this condition for two or three months. When fermentations take place in these piles nitrogen passes off in the air. This practice is objectionable because the soil under and around the piles gets most of the available plant food that is leached out, and the other soil does not receive its share. The result is that the succeeding crops grow uneven or in patches. There is no objection to dumping manure in small piles over the field if it is spread immediately The hauling of manure to the field and hand spreading it is perhaps the common method used in this country. It is difficult to spread manure evenly in this way and after the manure is distributed,

a brush drag should be used to scatter it more evenly. Manure spreaders distribute manure more evenly than any of the other methods in use. They are labor saving machines and although they usually carry less per unit of draft, they are considered a good investment for those who have much manure to spread. A ton of manure spread uniformly gives better results than a larger amount applied unevenly.

CHAPTER V.

HIGH GRADE NITROGENOUS FERTILIZER MATERIALS.

Nitrogen is the most important element to consider in the study of fertilizers. It is the most expensive and most fugitive of the essential elements. Nitrogen usually costs about three times as much as phosphoric acid or potash. To be in a form available as plant food it must be as nitrates which are readily soluble in water. The air is made up of nitrogen, carbon and oxygen and although plants utilize the carbon and oxygen most of them do not seem to be able to use the nitrogen. There is one class of plants, the legumes (peas, beans, peanuts, alfalfa, clover, etc.) of which we have spoken, that can utilize this elementary nitrogen but most of our other plants do not possess this power. The organic matter, which is made up of animal and vegetable matter, serves as a source of nitrogen, but plants cannot use it in this form. It is understood then that there is plenty of unusable nitrogen in the air and in soils rich in organic matter, but it has no direct plant food value in these forms until it is prepared by electrical means, oxidized and acted upon by certain bacteria.

Forms of Nitrogen.—Nitrogen exists in different forms in the many substances containing it. Not including the nitrogen in the air we may classify these forms into four groups, namely:

1. Organic nitrogen, which is found in vegetable and animal substances, generally as protein.
2. Ammonia nitrogen, which is found in ammonium sulphate.
3. Nitrate nitrogen, which is found in nitrate of soda (Chile saltpeter) and nitrate of potash.
4. Cyanamid nitrogen, which is taken from the air by electrical means and combined with calcium, carbon, etc.

Of these four forms all are soluble in water except organic nitrogen. The organic form is included in many substances, both animal and vegetable, while the remaining forms are found principally in a few products.

The Meaning of the Form of Nitrogen.—The fertilizer materials furnishing nitrogen contain this element in different forms. We have said that the substances containing nitrate nitrogen, ammonia nitrogen and cyanamid nitrogen are soluble in water and the organic nitrogen is insoluble in water. The nitrogen as nitrates is always the same and of equal value no matter from what substance it is derived. The ammonia nitrogen is also of equal value and equal quantities of it are as good no matter what material it comes from. The soluble nitrogen from ammonium sulphate, however, is not the same as the soluble nitrogen from nitrate of soda and the insoluble nitrogen of organic materials is not the same or of equal value. Therefore the source of soluble and insoluble nitrogen makes a difference in value of the forms of nitrogen. The solubility of nitrogenous substances influences the availability, or the rate with which the nitrogen in a suitable form is supplied so that the plant can assimilate it, to some extent.

The organic form of nitrogen is so called because the nitrogen is combined with other elements as hydrogen, carbon and oxygen in organic matter. Organic nitrogen is different in the various substances. Some animal and vegetable materials are quite rich in nitrogen while others do not contain much and are perhaps not so valuable. Some organic substances may contain considerable amounts of nitrogen but in such a locked-up state that they are undesirable as plant food.

When a substance gives up its nitrogen as nitrates readily we say that the nitrogen is in a form that is active; it is quick acting, quickly available, readily assimilated, etc. When the nitrogen is locked-up we use the terms slow acting, slowly available, etc. There are many degrees of availability of the different forms of nitrogen and they range from the very quick acting of the soluble materials to the organic materials that may take two or three years or even longer before they give up their nitrogen for plants to use as food. There are many organic substances that contain nitrogen, but in such small amounts, or in such a locked-up condition that they cannot be used profitably in the manufacture of fertilizers.

The principal sources of organic nitrogen will now be discussed.

The Vegetable Substances.

Cotton-seed meal is one of the most important sources of vegetable nitrogen. It is usually a bright yellow product with a nutty odor when fresh.

Attached[5] to the seed of cotton are long white fibers, or lint, known to us as cotton. When cotton is ginned most all of these fibers are removed, but a few short fibers always adhere to the seeds. The seeds are then taken to a cotton-seed oil mill and treated as

Fig. 5.—A cotton gin.

follows: First, the greater part of the short fibers are removed from the seed by a second ginning in a machine called the delinter. The seed is composed of the hull, or hard outer brownish black covering, and the kernel or meat. The seeds are then put in a machine called the huller which separates the hulls from the seeds. This process is called decorticating the seed. The whole mass (hulls and meats) is now subjected to a separating process by shaking in a revolving screen, the meats passing through the perforations of the screen. The hulls obtained in this process are known as cotton-seed hulls. The meats are conveyed from

the shaker to special steam-jacketed covered kettles and cooked. The cooked meats are transferred to a machine, called the cake former, where they are made up into cakes or forms of the proper size to fit the hydraulic press, and wrapped with camel's-hair cloth. These hot forms are now subjected to enormous pressure in a hydraulic press and the oil is removed. The remaining product is ground and sold as cotton-seed meal, although a great deal of it is shipped to foreign countries without being ground.

For the year 1908, 929,287,467 pounds of cotton-seed meal were manufactured in the United States.[29]

YIELDS OF PRODUCTS FROM A TON OF COTTON-SEED.[30]

Linters	23 pounds
Hulls	943
Crude oil (37.6 gals.)	282
Cake or meal	713
Waste	39
Total	2,000

Composition of Cotton-Seed Meal.—The composition of cotton-seed meal varies a great deal. When it is not adulterated with hulls the variation in composition may be due to the season, the nature of the soil and the climate. Seed raised on high land is usually richer in nitrogen than seed raised on low land. The Texas meals seem to run high in nitrogen. In the past few years many of the manufacturers have been introducing ground cotton-seed hulls into their meal which of course lowers the value of this product. Cotton-seed meal is in great demand as feed for live-stock and the bright yellow meals are used for this purpose. The darker meals are not so valuable as feed and are usually sold for fertilizer. The dark color may be due to over-cooking, to fermentation, or to storing in a wet or damp place. If there is no loss of nitrogen, the product is not injured for fertilizing purposes.

Commercial Classification.—The Inter-State Cotton-Seed Crushers' Association, which is made up of gentlemen dealing or interested in cotton-seed products, uses the following as a standard classification for cotton-seed meal:

Choice cotton-seed meal must contain by analysis 8 per cent. ammonia, which is equivalent to 6.58 per cent. nitrogen.

Prime cotton-seed meal must contain by analysis 7.50 per cent. ammonia, which is equivalent to 6.17 per cent. nitrogen.

Good cotton-seed meal must contain by analysis 7 per cent. ammonia, which is equivalent to 5.76 per cent. nitrogen.

Most of the meal is sold on an 8 per cent. ammonia basis. It also contains about 1.5 per cent. potash and 2.8 per cent. phosphoric acid.

Value of Cotton-Seed Meal.—Large quantities of this product are used in the South where it is especially suitable for the long growing crops as it supplies plant food during the whole season.

An insect, called the boll weevil, is reducing the acreage and yield of this crop. If the entomologists do not find a way of checking this pest the use of cotton-seed meal will be much less in the future.

A physical examination will not always indicate its fertilizing value. Many of the meals have the hulls so finely ground that it is impossible to detect the extent of their presence with the naked eye. The color of a meal is not always an indication of its nitrogen content. Always purchase cotton-seed meal under a strict guarantee as this product is variable in composition and a physical examination of it does not show its fertilizing value.

Linseed meal is another vegetable compound used for fertilizing purposes. It is a by-product in the manufacture of oil from flaxseed. There are two classes of linseed meal, namely, the old and new process meal. The old process meal is obtained by pressing out the oil from the cold or warmed crushed flaxseeds. In the new process the oil is extracted with naphtha and the naphtha driven off by steam. The old process and new process meal average about 5.3 per cent. nitrogen, 1.25 per cent. potash and 1.6 per cent. phosphoric acid. Linseed meal is not used extensively as fertilizer because of the high price it commands as feed for live-stock.

Castor pomace is the remaining product from the extraction of oil from the castor bean. It is poisonous to live-stock and

therefore is used for fertilizer. It averages about 5.5 per cent. nitrogen, 1.8 per cent. phosphoric acid and 1 per cent. potash. As it decomposes rapidly in the soil it makes an excellent fertilizer.

Rape meal is the ground product left after the expression or extraction of oil from rape seed. This product is not used much in the United States but as the cultivation of rape is increasing it was thought best to mention it. The high grade rape meal is usually fed for live-stock, but the lower grades, which contain weed seeds and impurities, are sometimes objectionable as feed but are valuable for fertilizer. Rape meal runs about 5 per cent. nitrogen and 1.6 per cent. phosphoric acid.

The Chief Animal Substances.

Dried blood is obtained from the large packing houses of the United States. There are two kinds on the market, namely, red and black blood. The red blood is obtained by drying blood very carefully with superheated steam and hot air. Should the blood be dried at too high a temperature it chars and turns black. If the blood is injured in any way it is sold as black blood. Red blood averages about 13.5 per cent. nitrogen with traces of phosphoric acid while black blood is a more variable product but usually contains 12 per cent. nitrogen and 1 to 3 per cent. phosphoric acid, depending upon the nature of the impurities. When bone is present the product contains sometimes as high as 4 per cent. phosphoric acid. Red blood is not used much for fertilizer because it commands too high a price for other purposes. Both red and black blood are ground and sold in a powdery condition. Black blood is a very valuable nitrogenous fertilizer which is in great demand and is very popular with the manufacturers of fertilizers in satisfying their formulas. It is one of the principal organic fertilizers used by manufacturers in the North. It is not used directly to any extent by farmers as the manufacturers purchase most of it. It is in a fine mechanical condition and is easy to mix with other materials. As plant food it gives excellent results as it decays very rapidly thus furnishing nourishment during the early stages of the growing period.

Sometimes salt and slaked lime are put in blood. It is very high in availability being somewhat quicker than cotton-seed meal.

Tankage is composed entirely of animal matter. It is the refuse from slaughter houses and consists of meat, bone, etc. (from which the fat has been extracted) and more or less dried blood. Animals condemned as unsuitable for food are made into tankage.

The phosphoric acid in tankage is slowly available as it is supplied principally by ground bone. The nitrogen is derived principally from meat and blood. When the percentage of bone is large, the phosphoric acid is high, and the nitrogen content is low, and when there is an excess of blood and meat, the nitrogen is high and the phosphoric acid low.

Grades of Tankage.—There are several grades of tankage on our markets. The most popular nitrogenous grades are those containing 8, 9, and 10 per cent. ammonia which are equivalent to 6.58, 7.41, and 8.23 per cent. nitrogen, and 6.56, 7.64, 10, and 12 per cent. bone phosphate of lime, which are equivalent to 3, 3.5, 4.58, and 5.5 per cent. phosphoric acid. There are many other grades of tankage sold that carry more phosphoric acid and less nitrogen, but these are classed as bone tankages and will be later described under phosphates.

Concentrated tankage is still another grade and the richest of all since it contains more nitrogen and is a more uniform product. It is made by evaporating wastes that contain animal matter in solution, or in other words the tank water. It usually contains 10 to 12 per cent. nitrogen and small amounts of phosphoric acid.

Variation in Tankage.—Because of the great variation in the chemical composition of tankage (no two shipments hardly ever run alike, for the manufacturers cannot seem to control the composition of their output on account of the variation in the by-products), great care must be exercised in purchasing. The product should be bought on its chemical composition and not necessarily on its guarantee, for it may or may not reach its stated composition. Hoof meal and hair are sometimes present in shipments of tankage. For sugar-cane, cotton-seed meal has been found to be more valuable than tankage of the same nitrogen content. Nevertheless, tankage is a valuable fertilizer and its

value depends a great deal on its nitrogen content. It is suitable for crops having a long growing season.

About 1,000,000 tons of tankage and dried blood are produced annually.

Azotin, meat meal, flesh meal, dried meat, animal matter and ammonite are practically the same product, but are by-products from different manufacturing establishments. Most of this product comes from the slaughtering houses and beef extract factories. It is a rich organic fertilizer containing about 13 per cent. nitrogen, but it may run higher or lower than this depending upon its purity. This product is made up generally of the flesh refuse of dead animals from which the fat has been extracted and the remains dried and ground. It is different from tankage because it does not contain bones.

Steamed horn and hoof meal averages about 12 to 15 per cent. nitrogen and is principally marketed by the large packing houses. The choice horns and hoofs are sold for the manufacture of buttons, combs, and novelties, and the imperfect and off-colored horns and hoofs are treated with steam, under high pressure, which renders the nitrogen more available and permits of the product being ground to a fine powder. Horn and hoof meal was not formerly thought much of, but since it has been subjected to superheated steam the product has been much sought after by the manufacturers of fertilizers. It is produced only in limited quantities and is not as valuable as dried blood, but has a fairly high degree of availability, according to recent investigations.

There is another method used in treating horns and hoofs, which consists of subjecting these materials to a dry heat, in a machine called the dryer, until they are brittle enough to pulverize or grind.

Production of Fertilizers by Packing Houses.—In 1905 the production of fertilizer by all the packing house concerns in the United States amounted to 211,137 tons. The animals slaughtered were 7,147,735 beeves, 10,875,339 sheep, 30,977,639 hogs, and 1,568,130 calves, or about 8½ pounds of fertilizer were obtained for each animal.[1]

Dry Ground Fish.—This is also called fish scrap and fish guano and has a yellow color. It is obtained principally from canning factories where the refuse as bones, skin, heads, fins, tails, intestines, etc., of edible fish are saved, dried and ground. Establishments expressing oil and manufacturing glue from inedible fish as Menhaden, furnish a considerable supply. The average annual catch of Menhaden is about 600,000,000 fish, which produce 70,000 tons of fish scrap and 35,000 barrels of oil. Thirty factories with 70 steamers are engaged in this industry, and the largest catch was in 1903 when 1,000,000,000 fish were caught.[31] The whale bone interests, after the bones are removed and the oil extracted from whales, utilize the remainder in the preparation of dry ground fish.

Dried ground fish is variable in composition depending upon the nature of the materials of which it is made. The greater the percentage of bone, the higher is the phosphoric acid content and the lower the nitrogen, and the less bone, the higher the nitrogen and the lower the phosphoric acid. The amount of oil left also influences the composition. It usually ranges from 7.5 to 10.5 per cent. nitrogen, 5.7 to 16 per cent. phosphoric acid, with an average of 8.5 per cent. nitrogen and 9 per cent. phosphoric acid. It is a popular and valuable fertilizer and large quantities are used in the North. Most sections of the South are too far away from where it is manufactured to prevent using it at its market value. Dry ground fish is readily decomposed in the soil and is therefore quick acting. It is not considered as valuable as dried blood.

King crab is obtained on the Atlantic coast and is dried and ground, in which state it is utilized by fertilizer manufacturers. It contains about 10 per cent. nitrogen and is similar to dried ground fish in fertilizer properties.

Guano, or natural guano, is another important source of nitrogen. It was used as early as the 12th century in Peru. On the west coast of South America there are thousands of sea fowl. These birds have roosting and breeding places along the uninhabited portions of the coast and many of them make their home on the smaller islands off the coast of Peru and also on the main-

7

land, because of the abundant supply of fish in that region. The excrement voided by these birds is rich in nitrogen and phosphoric acid because their food, which is fish, is rich in these constituents. During breeding seasons they literally cover these islands and the young birds after they are hatched are fed on fish until they are able to fly. The excreta from the old and young birds, feathers, and the remains of the young birds that die,

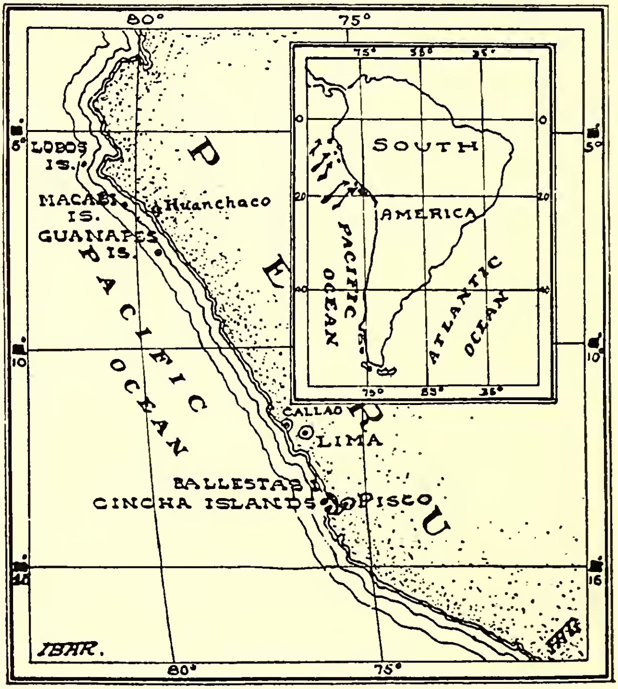

Fig. 6.—Map showing location of Peruvian Guano Islands.

all go to make up guano. As this region is practically rainless and has a dry hot temperature, these remains dry out rapidly and are preserved without much loss of phosphoric acid or nitrogen. There is some loss of nitrogen in these Peruvian guanos due to the formation of ammonium carbonate, a volatile form, and to leaching by occasional rains. However, these deposits have been

the best nitrogenous guanos in the world. There are deposits in other parts of South America, West Indies, Africa, Australia, Asia, and the islands of the Pacific, but the Peruvian deposits are the most notable. There is a wide difference in the composition of guanos. In Peru, guano from the same island shows variation in chemical composition, while guano from different islands shows even a greater variation. The oldest deposits usually contain less nitrogen and more phosphoric acid than the more recent. In a wet, damp climate fermentation, aided by

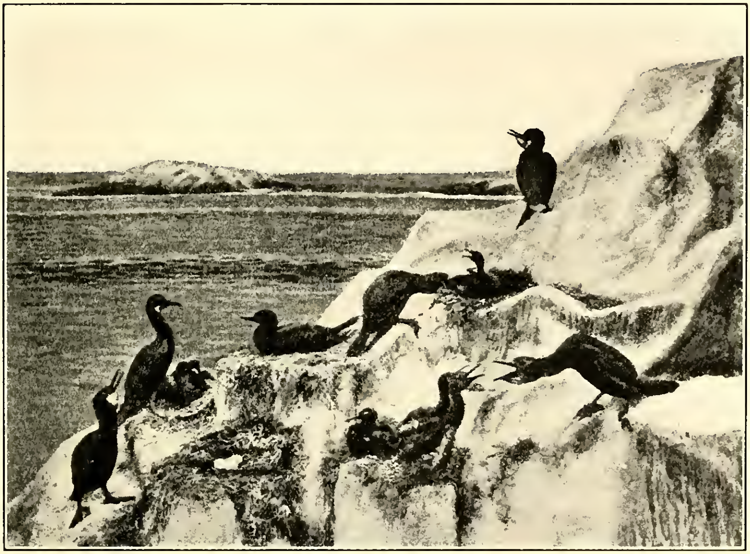

Fig. 7.—Cormorants.

the presence of moisture, destroys all or most of the organic matter driving off the nitrogen as ammonium carbonate. Soluble phosphoric acid is also lost in such regions. Therefore it is easy to understand the wide differences in the composition of these deposits.

Guanos range from rich nitrogenous deposits to phosphatic deposits which only contain traces of nitrogen and considerable amounts of phosphate of lime. There are therefore two classes

of guanos, namely, nitrogenous and phosphatic. The phosphatic guanos will be discussed under phosphates.

Formerly guano was used more extensively in the United States but most of the nitrogenous deposits have been exhausted so that the importations are rather decreasing from year to year. There were 16,155 tons imported from Peru in 1905 and 5,500 tons in 1909.[32]

The nitrogen in guanos is present in different forms. Some of it is as nitrates, some as ammonia and some as organic nitrogen. The presence of these various forms makes the nitrogenous guanos valuable because they supply plant food during the whole growing season.

ANALYSIS OF CHINCHAS GUANO, 1897.[9]

	Per cent.	Per cent.
Nitrogen as nitrate	0.32	——
Nitrogen as ammonium salts	3.94	——
Nitrogen as uric acid	8.85	——
Nitrogen in other organic forms	2.98	——
Total nitrogen	——	16.09
Phosphoric acid soluble in water	2.63	——
Phosphoric acid (reverted)	6.29	——
Phosphoric acid (insoluble)	0.37	——
Total phosphoric acid	——	9.29

Guano does not contain appreciable amounts of potash. It is a fertilizer that does not require much intelligence to apply as it does not injure crops in any way.

Sometimes Peruvian guano is acidulated with sulphuric acid to convert the volatile ammonium carbonate into ammonium sulphate, which is a stable compound, and to make the phosphoric acid soluble. This product is called dissolved Peruvian guano and is a better fertilizer than the original material because the nitrogen is saved and the phosphoric acid rendered available as plant food.

The Ichaboe guano, obtained from the Island of Ichaboe on the west coast of Africa, is a recent deposit and is being worked, but it is inferior to the Peruvian guanos that were formerly shipped. The following table gives the composition of nitrogenous guanos. Those printed in italics are being worked.[24]

	Nitrogen Per cent.	Phosphoric acid Per cent.
Angamos	20	5
Chincha	14	13
Ballestas	12	12
Egyptian	11	19
Guanape	11	—
Macabi	11	12
Corcovadc	11	15
Saldanha Bay	9	9
Ichaboe	8	9
Independence Bay	7	12
Pabellon de Pica	7	14
Punta de Lobos	4	15
Huanillos	6	13
Penguin	5	11
Patagonian	4	18
Falkland Islands	4	14

In Mexico there are deposits of bat guano, many of which are good nitrogenous fertilizers, but they are not being worked because of poor transportation facilities. There are also deposits of bat guano in Texas. The bat guanos are not as a rule valuable as the high grade nitrogenous Peruvian guanos. For the composition of bat guanos refer to the chapter of Farm Manure.

Ammonium sulphate is unlike the organic compounds as it is not a natural product but a manufacturing by-product. When pure it is a white crystalline salt but sometimes foreign substances become mixed with it, in the course of manufacture, which causes it to be grey, yellow, or blue. It is soluble in water and volatile, that is it will pass off as gas when strongly heated over a flame. It is derived from the distillation of coal in the manufacture of gas; from the distillation of bones in the manufacture of bone-black; and from the manufacture of coke from coal. Coal was formed vegetable matter and most coals average about 1.8 per cent. nitrogen. When coal is heated, as in the manufacture of gas or coke, about ⅕ of the nitrogen as ammonia is driven off and this ammonia may be saved by washing it in water in special apparatus. The solution thus formed is then distilled into sulphuric acid, concentrated and the crystals of sulphate of ammonia separate out on standing. Bones contain about 3 to 4.5

per cent. nitrogen and the nitrogen as ammonia is recovered in a similar way as in distilling coal or coke, when they are subjected

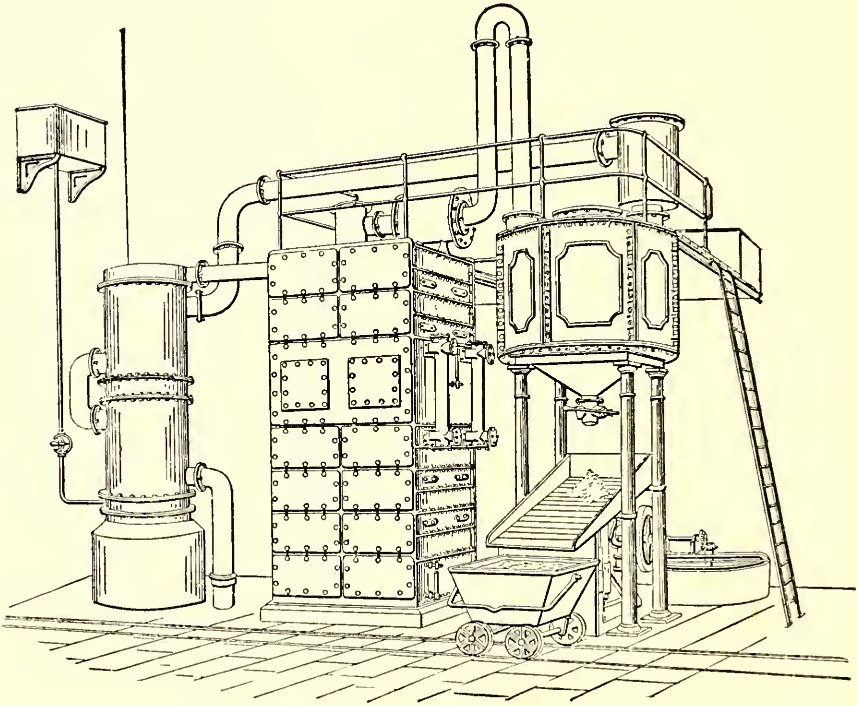

Fig. 8.—Old process of manufacturing ammonium sulphate.

to dry distillation by heat, as may be practiced in the manufacture of bone-black.

The Direct Process.—There is another process called the direct process for recovering ammonia from coal, etc., that is being used in Germany. In this process the ammonia in the gas is combined directly with sulphuric acid forming sulphate of ammonia, thus doing away with the ammonia washers. The direct process has many advantages. It reduces the equipment; the operation is simpler; the consumption of water is less; ammonia stills are not required. In other words, the direct process is much less expensive, promises to revolutionize the recovery of am-

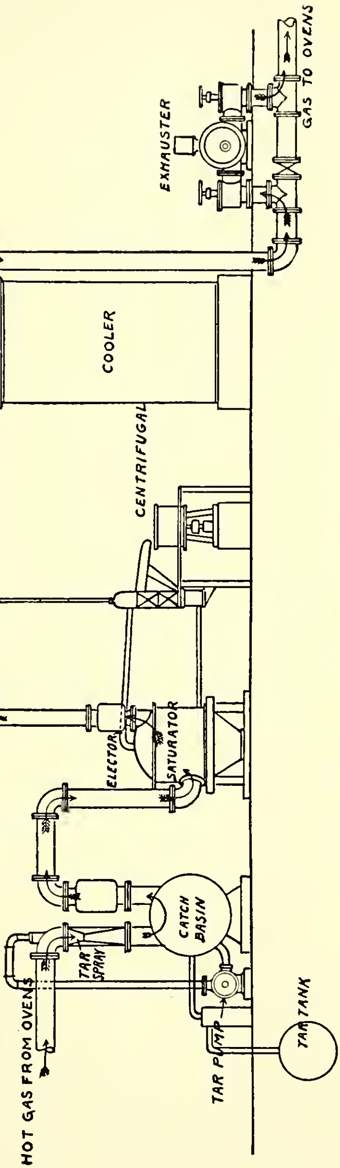

Fig 9.—Direct process for re-covering ammonia.

monia in coal and coke, and should cause a greater production of sulphate of ammonia in the United States.

About 1 per cent. of the weight of the coal carbonized is sulphate of ammonia, so that for the production of 5 tons, 500 tons of coal must be treated.

TABLE SHOWING PERCENTAGES OF AMMONIA, PURE AMMONIUM SULPHATE, NITROGEN, AND POSSIBLE IMPURITIES IN COMMERCIAL SULPHATE OF AMMONIA.[1]

Ammonia Per cent.	Ammonium Sulphate Per cent.	Nitrogen Per cent.	Impurities Per cent.
25.796	100.00	21.203	0.00
25.7	99.63	21.12	0.37
25.6	99.24	21.04	0 76
25.5	98.85	20.96	1.15
25.4	98.46	20.88	1.54
25.3	98.08	20.79	1.92
25.2	97.69	20.71	2.31
25.1	97.30	20.63	2.70
25.0	96.91	20.55	3.09
24.9	96.52	20.47	3.48
24.8	96.14	20.38	3.86
24.7	95.75	20.30	4.25
24.6	95.36	20.22	4.64
24.5	94.97	20.14	5.03
24.4	94.59	20.06	5.41
24.3	94.20	19.97	5.80
24.2	93.81	19.89	6.19
24.1	93.42	19.81	6.58
24.0	93.04	19.73	6.96
23.9	92.65	19.64	7.35
23.8	92.26	19.56	7.74
23.7	91.87	19.48	8.13
23.6	91.49	19.40	8.51
23.5	91.10	19.32	8.90
23.4	90.71	19.23	9.29
23.3	90.32	19.15	9.68
23.2	89.94	19.07	10.06
23.1	89.55	18.99	10.45
23.0	89.16	18.90	10 84

Extent of Manufacture.—This product is manufactured extensively in England and Germany. About 348,000 tons were produced in England and 325,000 tons in Germany for 1909. About 100,000 tons will approximate the output in this country but the tonnage will in all probability be much larger as many of

[1] American Coal Products Co.

the coke ovens in the United States are not saving the ammonia. About 40,000 tons of ammonium sulphate were imported for 1909 mainly from England.[32] On account of this product containing such a high content of nitrogen it may sometimes be purchased cheap, as the freight per unit of nitrogen is less than when a product containing less nitrogen is selected.

Composition and Availability.—Sulphate of ammonia when pure contains 21.2 per cent. nitrogen but the commercial article usually runs about 20 per cent. It is in a form very suitable for distribution in the soil and is readily converted into available plant food. It more available than the organic forms. It is a quick acting fertilizer and suitable therefore for quick returns in crop production, an especial advantage for truckers and market gardeners. It is sometimes substituted for nitrate of soda.

It is usually a uniform product and adulterants are not often added to it. Should adulteration be expected the following tests may suffice to prove its purity. It should dissolve in water; it should have the appearance of salt; it should pass off as gas when a small quantity is heated red hot on a shovel or iron plate.

As it is readily soluble in water it should be used sparingly, and frequent small applications are more effective than large amounts applied at long intervals. A continued use of it may cause the soil to become acid because of the sulphates left in the soil after the nitrogen is given up.

Nitrate of Soda.—This is a white or yellow or pink crystalline salt. The nitrogen in nitrate of soda is in a form that can be used by plants without undergoing any change. Nitrate of soda is the highest in point of availability of any of the nitrogenous fertilizer materials. It induces roots to grow deep. The nitrate diffuses into the subsoil and the plants send down their roots for it. This is indeed of great benefit because it enables the plant to better stand dry spells and it increases the area of plant food supply.

Deposits and Shipments.—It is found in extensive deposits on the west coast of Chile and is often called Chile saltpeter. There is a difference of opinion regarding the origin of these deposits

but it is thought that they were formed by the decomposition of

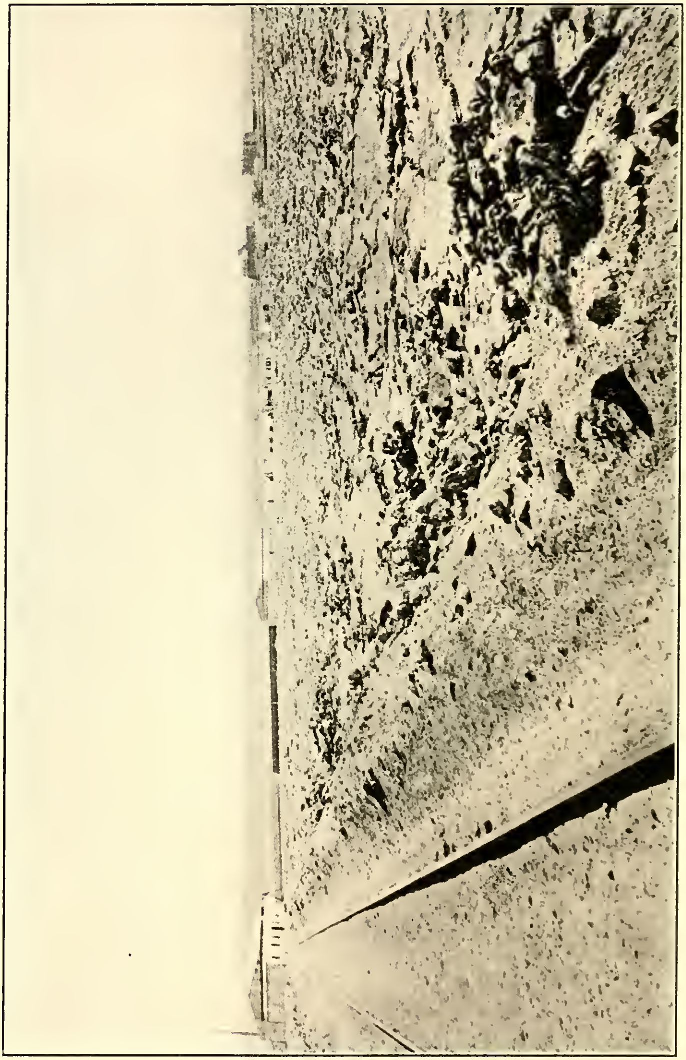

Fig. 10.—General view of nitrate grounds and works.

marine vegetation, as seaweed in combination with sea salt. The exportation of nitrate of soda brings a vast revenue to

the Chilian government. The export duty per year amounts

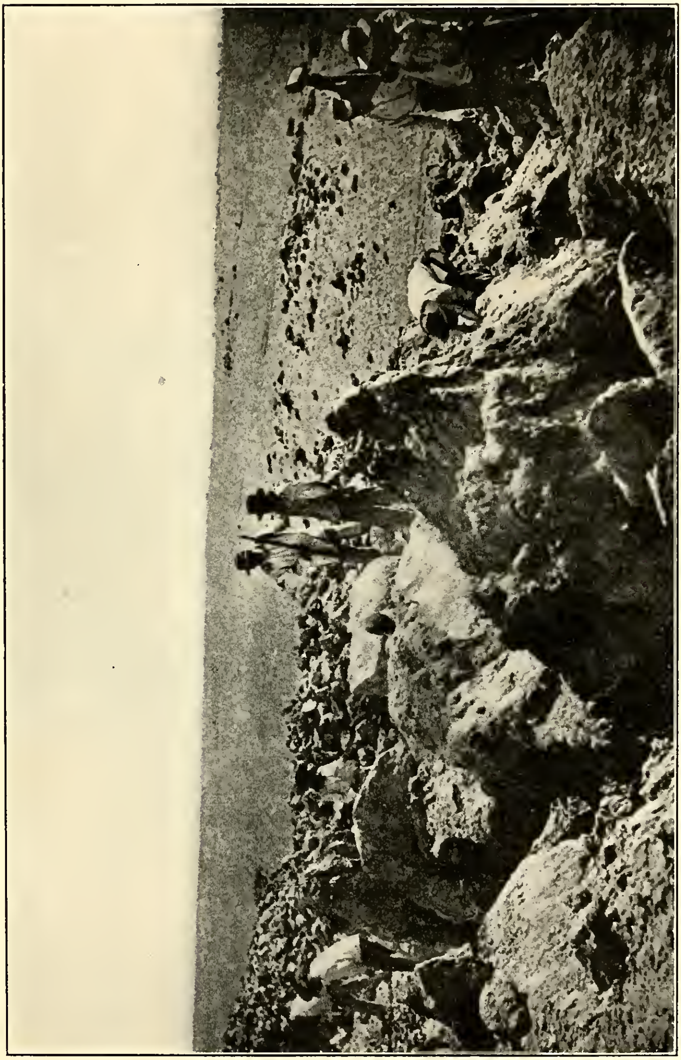

Fig. 11.—Opening up trench after blasting, showing extraction of caliche by piece work.

to about $20,000,000 or approximately three-fourths of the income of that country. The exportation of this salt started in

1830 with a trial shipment of about 9,000 tons and the total exportation from 1840 to 1904 amounted to 25,947,994 tons. From 1904 to 1923 it is estimated that 35,336,180 tons will be exported. Up to and including 1909 about 40,000,000 tons were shipped.[33]

SHIPMENTS OF NITRATE OF SODA FOR 1908-9.[32]

	1908	1909
Production	2,075,039	1,947,603
Europe	1,583,278	1,644,505
United States	453,831	326,818
Other points	70,401	55,367
Total shipments	2,107 510	2,026,690

The value of this product may better be realized when it is known that it has a wholesale market value of $45 to $53 per ton in this country. A great deal of it is used for the manufacture of explosives. The following shows the amounts used for the manufacture of fertilizers.[32]

1900 Tons	1905 Tons
17,203	40,234

Caliche.—The native deposit of nitrate of soda is called caliche. Caliche contains from small percentages to 60 per cent. nitrate of soda. It is not worked at present unless it contains about 18 per cent. nitrate of soda. Impurities as sodium chloride, potassium sulphate, calcium sulphate, sodium sulphate, magnesium sulphate, etc., are associated with the nitrate of soda. The caliche is found in layers sometimes 6 feet thick, about 2 to 10 feet below the surface, and is blasted out with more or less earthy matter which adheres to it. It is put in vats where it is dissolved in hot water and steam. After it is dissolved the solution is piped to crystallizing pans where the crystals of nitrate of soda separate out on cooling. The mother liquor is saved and used over again.

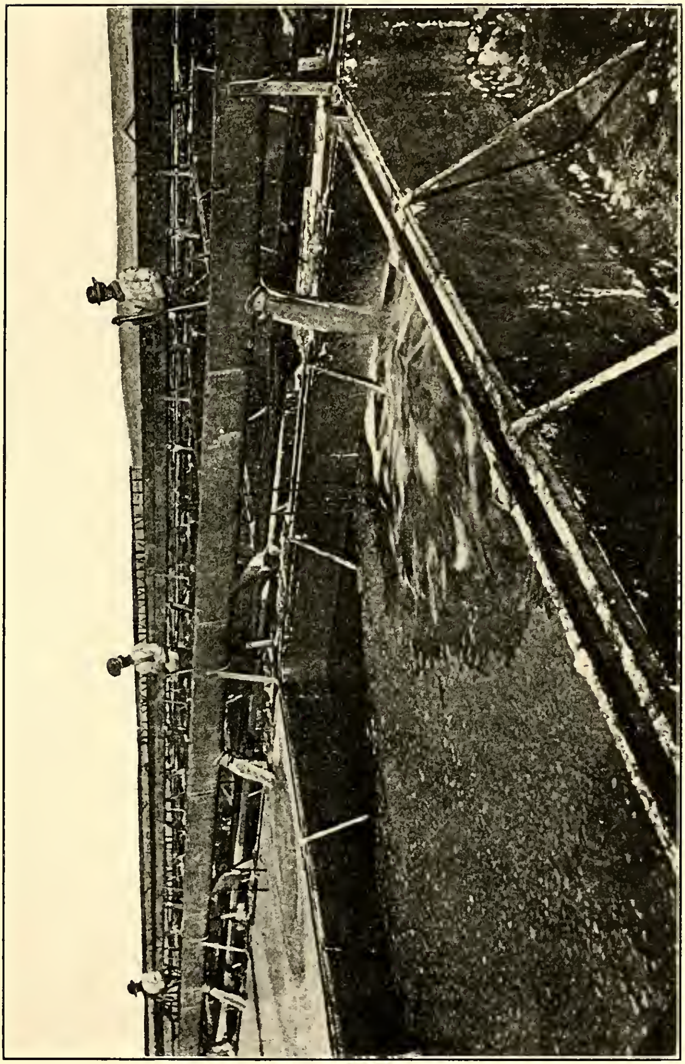

Fig. 12.—Crystallizing pans full, filling and empty.

ANALYSIS OF NITRATE OF SODA CRYSTALS AFTER BEING DRIED IN THE SUN.[9]

	Per cent.		Per cent.
Sodium nitrate	94.164	Calcium sulphate	0.102
Potassium nitrate	1.763	Magnesium snlphate	0.219
Sodium chloride	0.933	Potassium perchlorate	0.282
Sodium iodate	0.010	Water	2.100
Insoluble matter	0.138		
Magnesium chloride	0.289	Total	100

Composition and Properties.—Nitrate of soda contains 15 to 16 per cent. nitrogen and the average product found on the American market contains 15.3 per cent. nitrogen. It is very soluble in water and therefore it should be supplied in small quantities frequently to prevent losing it by leaching. It should be kept in dry storage as it absorbs water and is liable to liquefy. It is hard to distribute evenly on the soil unless it is mixed with earth or some other material. On account of its caustic action it should be applied around the plants and not on them as it spots green vegetation. It should be kept away from live-stock as it is poisonous. Acid phosphates when damp should not be mixed with nitrate of soda as nitrogen is lost. The acid attacks the nitrate of soda liberating the nitrogen.

A continued use of nitrate of soda prevents losses of carbonate of lime from the soil. The following experiment was conducted for 40 years.[9]

Fertilizer	Per cent. in fine dry soil		Loss per acre per year
	1865	1904	lbs.
Unmanured	4.54	3.29	800
Complete minerals and 275 lbs., nitrate of soda	4.24	3.36	564
Complete minerals and 400 lbs. ammonium salts	3.82	2.25	1,010
Farm manure	4.20	3.28	590

Nitrate of soda reduced the loss of carbonate of lime considerably, from 236 pounds to 446 pounds respectively.

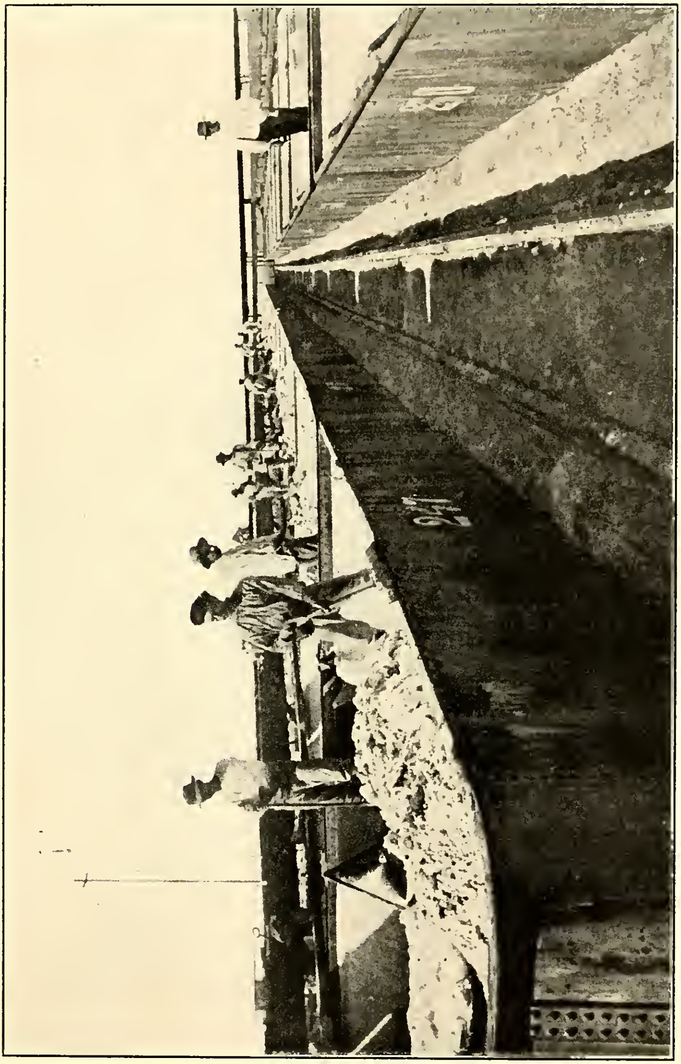

Fig. 13.—Crystallizing pans after running off mother liquor.

Nitrate of soda used continuously and abundantly is liable to put the soil in poor condition, as the sodium is not taken up by the plant as rapidly as the nitrogen, and is left behind as sodium carbonate. The compacting of soils due to nitrate of soda may be relieved to a certain extent by applications of acid phosphate and ammonium sulphate, which have acid reactions in the soil and tend to neutralize the alkaline condition due to the nitrate of soda.

The utilization of nitrogen from the air by artifically uniting and fixing it with other elements to form compounds that could compete with the other nitrogenous fertilizer materials has attracted the attention of chemists and investigators for many years. It seems that at last the problem has been solved and it is now only a matter of a short time when the present modes of manufacturing artificial nitrogen compounds will be so perfected that we will not be forced to worry about the future supply of this important element. There are two of these artificial nitrogenous compounds being sold to-day, namely, calcium nitrate and calcium cyanamid.

Calcium nitrate sometimes called lime nitrogen, $Ca(NO_3)_2 4H_2O$, is manufactured by the Berkeland-Eyde process, with cheap water-power, in Notodden, Norway. A brief description of the process may be of interest.

Process of Manufacture.—The nitrogen is united with oxygen at a high temperature (2,600° C. to 3,000° C.) with the aid of an electric arc flame. Hall says:[9] "In the Berkeland-Eyde process an alternating current at about 5,000 volts is set to form an arc between U-shaped copper electrodes, which are hollow and kept cool by a current of water within. The electrodes are placed equatorially between the poles of a powerful electromagnet, which has the effect of causing the arc to spread out into a broad flat flame. Though the temperature of the arc-flame is calculated to be 2,600° C., it is not particularly luminous: it may be looked directly from a yard's distance.

"Through the furnace in which this special arc is generated about 15,000 liters[1] of air are blown per minute at gentle pres-

[1] One liter equals 1.057 quarts.

sure and the issuing air contains about 1 per cent. of nitric oxide and is at a temperature of 600° to 700° C. It is cooled and then passes into two oxidizing chambers, where the combination of the nitric oxide with the oxygen of the uncombined air takes place, after which it passes into a series of five condensing towers. Down the fourth tower, which is filled with broken quartz, water trickles and picks up enough of the nitrous gases to become 5 per cent. nitric acid at the bottom; this is pumped up and trickles down the third tower, the process being repeated until the liquid leaving the bottom of the first tower contains 50 per cent. of nitric acid. In the fifth and last tower the absorbing liquid is milk of lime, and the resulting mixture of solution of calcium nitrite and nitrate is treated with enough, of the previously formed nitric acid to convert it wholly into nitrate, the nitrous fumes evolved being led back into the oxidizing chambers. The product is then concentrated until it solidifies as a material containing about 13 per cent. of nitrogen, or 75 per cent. of pure calcium nitrate.

"The present factory has three electric furnaces installed, each employing 500 kilowatts, and the production amounts to about 150 kilograms[1] of nitrogen fixed per kilowatt year.

Output and Value.—"Berkeland calculates that the cost of manufacturing calcium nitrate containing 13 per cent. of nitrogen is about $20 per ton, and that it can be sold at a profit at $40 a ton, which would be equivalent to nitrate of soda at about $50 a ton. The present large factory at Notodden has been putting calcium nitrate on the market for two years or more, the rate of production now being about 20,000 tons per annum. When the extensions to the factory are completed it is expected the output will amount to nearly 3,000 tons per month. As a fertilizer there cannot be the least doubt that nitrate of lime will be just as valuable, nitrogen for nitrogen, as nitrate of soda. At Rothamstead a chemically prepared nitrate of lime has been used for two or three years for a special purpose on one of the mangold plots, and it has given exactly equal results to the nitrate of soda plot alongside. Many field experiments have

[1] One kilogram equals 2.20 pounds.

been carried out with the electrical product in Norway during the last year or two, and have shown that the new material can be strictly valued against nitrate of soda on the basis of the nitrogen it contains. Indeed, on some soils it is likely to be more valuable, because, as will be shown later, part at least of the lime base will be left behind in the soil as calcium carbonate. This will be an advantage in peaty soils, and will also save clay soils from the peculiar wetness and stickiness which results from the employment of much nitrate of soda."

Calcium cyanamid is a grey black crystalline powder. It is

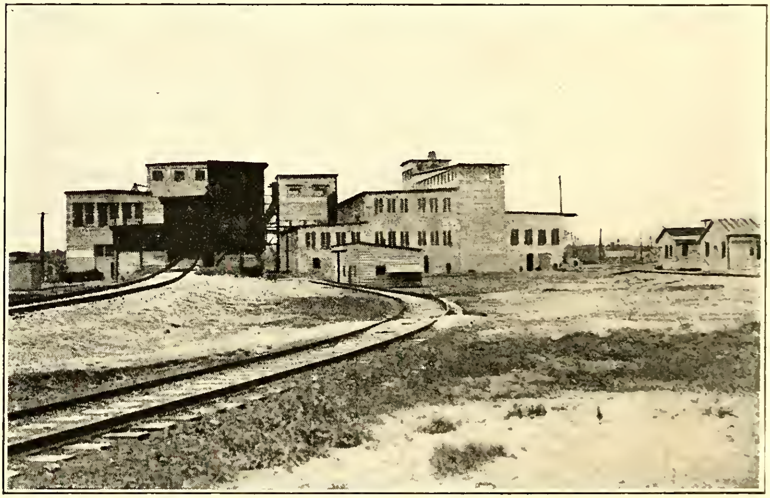

Fig. 14.—American Cyanamid Co. Plant, Niagara Falls, Ont.

made from limestone, coke and nitrogen gas. The first step in the manufacture of this compound consists in the production of calcium carbide which is made by heating a mixture of coke and limestone in an electric furnace under a high temperature (1,100° C.) The following is the reaction:

$$CaO + 3C = CaC_2 + CO.$$

The carbide is powdered and introduced into air-tight coal-fired retorts. After the carbide has reached a white heat pure nitrogen gas is passed over it and the carbide absorbs the nitro-

gen gas, forming calcium cyanamid. The nitrogen gas is obtained by passing air over red-hot copper, which removes the oxygen by forming copper oxide which is reduced again to metallic copper by passing coal gas over it. There is another process called the liquid air process used, wherein the nitrogen gas is obtained by fractional distillation from liquefied air, the nitrogen being evaporated at a lower temperature than the oxygen.

The calcium cyanamid as it comes from the retorts is cooled in air-tight receptacles, powdered and packed for the market. The reaction is:

$$CaC_2 + N_2 = CaCN_2 + C.$$

The composition of calcium cyanamid is about as follows:[32]

	Per cent.
Calcium cyanamid ($CaCN_2$)	57
Carbon	14
Lime (CaO)	21
Silica	25
Iron oxide	4
Calcium sulphide, phosphide, and carbonate	1.5
Nitrogen	20

When calcium cyanamid was first placed upon the market small quantities of carbides, sulphides and phosphides were present which are undesirable for fertilizing purposes as they are decomposed by the moisture in the soil forming acetylene, sulphuretted hydrogen and phosphine. These gases are poisonous to plants and especially injurious to young germinating plants. Considerable experimentation was done by the manufacturers to rid cyanamid of these poisonous substances and a product is now claimed to be manufactured in Baltimore, Md. by the American Cyanamid Co., in which these poisonous materials are absent. This new product is known as, "Improved Cyanamid" and has the following proximate composition:[32]

	Per cent.
Calcium cyanamid	29.26
" carbonate	0.21
" nitrate	20.06
" hydrate	28.78
Sodium cyanamid	10.38
Free carbon	7.89
Silica	1.03
Alumina	1.37
Iron oxide	0.69
Not determined	0.33
	100.00
Total nitrogen	17.01
Total calcium oxide	34.73
Nitrate nitrogen	3.39
Cyanamid nitrogen	13.62

Properties.—About 80 per cent. of the nitrogen in the improved cyanamid is as cyanamid and the remaining 20 per cent. as nitrate. Calcium cyanamid contains about 20 per cent. of free lime which absorbs water and carbonic acid gas from the air, causing the lime to slake and the product to decompose so that ammonia is formed. This ammonia is not lost to any great extent when the product is kept in bags, but if it is exposed in a loose pile the loss may be appreciable. Calcium cyanamid is soluble in water and when steam is introduced into it ammonia is driven off. In the soil the ammonia is given off by the action of water and soil micro-organisms. The action with water is:

$$CaCN_2 + 3H_2O = CaCO_3 + 2NH_3.$$

Fertilizing Value.—Experiments show that this product has about the same fertilizing value as ammonium sulphate on most soils. It is therefore highly available. It would no doubt show to good advantage on soils deficient in lime. Care should be exercised in its application. When the product contains injurious substances it is liable to injure seedlings and it is safe practice to apply it sometime before the seed is planted. It is thought to be injurious when used as a top dressing but this point has not been thoroughly proved. Should the "Improved Cyanamid" be free from injurious substances it will prove a much more desirable fertilizer.

On the Rothamstead soil which contains an ample supply of lime as carbonate, the following results were obtained.[9]

Fertilizer	Barley		Mangolds roots		
	Grain Bushels	Straw Pounds	Tons	Tons	Tons
Calcium cyanamid	34.3	1,900	22.0	11.1	28.9
Sulphate of ammonia	37.5	2,400	23.5	10.0	27.9

COMPOSITION OF HIGH GRADE NITROGENOUS MATERIALS.

Materials	Nitrogen Per cent.	Phosphoric acid Per cent.	Potash Per cent.
Cotton-seed meal	6.58	2.80	1.50
Linseed meal	5.30	1.60	1.25
Castor pomace	5.50	1.80	1.00
Rape meal	5.00	1.60	—
Red blood	13.50	—	—
Black blood	12.00	—	—
Tankage	6.58-7.41	3-5.5	—
Concentrated tankage	10-12	—	—
Azotin	13.00	—	—
Steamed horn and hoof meal	12-15	—	—
Dry ground fish	8.50	9.00	—
King crab	10.00	—	—
Guano	4-12	5-20	—
Ammonium sulphate	20.00	—	—
Nitrate of soda	15.30	—	—
Calcium nitrate	13.00	—	—
Calcium cyanamid	16-20	—	—

CHAPTER VI.

LOW GRADE NITROGENOUS MATERIALS AND FUNCTIONS OF NITROGEN.

The nitrogenous substances discussed in the previous chapter are all considered high class and valuable standard materials. Some of them as the mineral compounds are immediately or almost immediately available, while the organic materials, both animal and vegetable, vary in their degree of availability, but stay with the crop during the whole or the greater part of the season.

The high prices of these desirable and valuable nitrogenous materials have caused some of the manufacturers of commercial fertilizers to seek and use cheaper sources of nitrogen. Many of these cheaper materials, to be sure, are rich in nitrogen but really of little value as the nitrogen is present in such forms as to be inert or else too slow acting to stimulate plant growth. Many of these low grade nitrogenous waste products are imported from foreign countries yet we produce our share of them in this country. They are made up of wastes from the manufacture of silk, wool, feathers, combs, hair, skins, sugar and some few are derived from vegetable sources. The materials most commonly used will be discussed.

Raw Leather Meal.—This product contains about 8 per cent. nitrogen, which is in a form that is very slowly utilized by plants; it may remain in the soil for two or three years before decaying. It takes such a long time for it to decompose that it has not much value for fertilizing purposes. One of the objects in the treatment of leather is to prevent its decay and for this reason raw leather may remain in the soil for a very long time before undergoing any change. This material is sold varying in the degree of fineness from a dust to coarse particles. If it is ever used it should be powdered. At best it is a tough material.

Dissolved leather, sometimes called treated leather or extracted leather, is made in Belgium. The raw leather is roasted and

very finely ground and treated with superheated steam which removes most of the tannic acid. It is then acidulated with sulphuric acid to fix the nitrogen and render it more available. This material is being used by the manufacturers in the United States to quite a considerable extent because it is cheaper than the more desirable nitrogenous materials per unit of nitrogen. This product contains about 8 per cent. nitrogen and is more valuable than raw leather.

Feather waste and various skin wastes are also saved for fertilizing purposes.

Hair and fur waste is rich in nitrogen. It is unsuitable as fertilizer because it is so slowly decayed. When properly treated with sulphuric acid and rendered assimilative for plants it is more valuable. Hair to a limited extent is often found in tankage.

Mora meal is a vegetable product, brown in color, which is imported from Europe. The mora seed, which are grown in India and probably other tropical countries, are sent to Europe where they are subjected to pressure and the oil extracted. The remaining pomace is ground and sold as mora meal. This product has been used for the past nine years in the United States and the consumption has increased every year.

It carries about 2.5 per cent. of nitrogen which is of low availability. It is not sold with any guarantee of nitrogen, phosphoric acid and potash, but on a flat basis. It is used by manufacturers of commercial fertilizers principally as a dryer and filler. It is good for both of these purposes because it is an excellent absorbent and bulky.

The quantity available from year to year depends upon the amount of seed raised and on the price. European pressers will not handle it unless the price of the seed is such that they can make a profit.

Beet Refuse.—This compound is a grey black powdery substance. It contains from 5 to 7 per cent. nitrogen and about 0.5 to 1 per cent. potash. One manufacturer used this compound in some of his mixtures because he believed it would kill insects

in the soil. He believed this because of the presence of sulphocyanic acid in this compound.

Scutch.—This is a by-product or waste product in the manufacture of glue and the dressing of skins. It is manufactured in England and contains about 7 per cent. nitrogen.

Horn and hoof meal, horn shavings, etc., are products obtained from slaughtering houses or by-products in the manufacture of combs and similar articles. In the raw state they are extremely hard to grind and are not valuable in this form because they decay too slowly to supply plant food with any degree of rapidity. When steamed and pulverized they become high grade products as mentioned in the previous chapter.

Wool Waste, Shoddies, Etc.—"Shoddy should consist of the short, broken fragments of wool which are rejected in the various processes for preparing woollen fabrics because they are not long enough to make up into yarn, but now the term is applied more generally to any form of waste from silk or wool manufacturing which is no longer profitable to work up for cloth. The material is thus extremely valuable in composition; pure wool contains over 17 per cent. of nitrogen, pure silk about as much, and at one end of the scale of shoddies come materials like carpet waste, cloth clippings, gun wad waste, which are nearly pure and may contain as much as 14 per cent. of nitrogen. Less valuable, because of the greater admixture of dirt, are wool combings, flock dust, and other cloth wastes where cotton is also used, these may have 5 to 10 per cent. of nitrogen: while lower still come the manufacturing dust from textile factories, the sweepings of workshops, etc., in which the nitrogen may fall as low as 3 per cent."[9]

These products are all slow to decay and are rather undesirable as fertilizer. Shoddy and wool waste are often coarse and bulky and hard to mix in a manufactured fertilizer or to distribute evenly when applied to the soil.

Dissolved Wool, Shoddy, Etc.—Wool waste, shoddy, etc., are sometimes treated with superheated steam, the liquid evaporated to dryness and the product ground, or else they may be acid-

ulated with sulphuric acid for a long time (2 months) to render the nitrogen available. When treated by either of the above methods, they are known as dissolved wool, shoddy, etc., and are of course more valuable than the raw products from which they were made.

Garbage Tankage.—Many of the large cities have plants where the garbage is accumulated. The garbage is digested with hot water and steam in special digesters for about 6 to 8 hours. It is then subjected to hydraulic pressure and the grease is obtained. The grease is separated from the extracted water; this latter product is evaporated and the residue mixed with the pressed tankage and dried to a low moisture content. The product is then screened and ready for sale. It carries about 2 to 4 per cent. of nitrogen, 2.5 to 5 per cent. of phosphoric acid and about 0.3 to 1.5 per cent. of potash. Garbage tankage is slowly assimilated by plants and is not a valuable fertilizer.

Dried peat, sometimes called dried muck, is used principally by the manufacturers because of its excellent drying properties. The use of it enables the manufacturer to put out a fertilizer in a fine mechanical condition which may be distributed evenly on the soil. This material varies in composition, depending on the amount of vegetable and mineral matter present, but may be considered as averaging 1.5 to 2 per cent. of nitrogen.

Availability of Nitrogenous Fertilizer Materials.—The only correct way to determine the value of any nitrogenous substance is by running experiments with growing plants. The high grade products as nitrate of soda, sulphate of ammonia, dried blood, cotton-seed meal, linseed meal, castor pomace, dry ground fish, tankage, ground bone, steamed horn and hoof meal, etc., have been tested by field experiments to determine their crop producing power. Laboratory methods have been introduced to correspond as near as possible with the field results.

The availability of nitrate of soda is always taken as 100 and the availability of other materials is based on the results secured when compared to nitrate of soda. Should nitrate of soda give an increased yield of 500 pounds per acre for a crop, the yield

of a nitrogenous fertilizer of 75 per cent. availability would give an increase of 375 pounds, etc.

Not Always Possible to Run Field Experiments.—To conduct field experiments is often impossible, because of the great expense, the long time required, the difference in soils, the variation in seasons, the ability of the various crops for securing plant food, the association with other fertilizing materials containing phosphoric acid, potash, lime, etc., so that much of our information on the low grade products has been worked out in the laboratory by chemical methods. These methods are not entirely satisfactory but indicate to a great extent the relative values of nitrogenous fertilizers, as to whether they are high grade, medium grade or low grade. The Vermont and Connecticut Experiment Stations have done considerable work along this line.

Vegetation Experiments.—Wagner conducted some vegetation experiments on the relative availability of some nitrogenous materials. Summer rye, followed by flax, summer wheat and carrots were used in these experiments.

Results of Wagner's Experiments. The Relative Availability of Various Forms of Organic Nitrogenous Matter.[34]

	The experiments of first year	Average of first and second year's experiments	Average of first second and third year's experiments
Nitrate of soda	100	100	100
Sulphate of ammonia	85	74	88
Peruvian guano	84	88	80
Blood meal	67	67	69
Castor pomace	62	65	67
Green crop manure	62	60	68
Horn meal	63	61	63
Fish guano	51	59	64
Steamed bone-meal	42	53	61
Flesh meal	44	47	54
Wool dust	27	28	33
Stable manure	11	16	32
Leather meal	13	12	20

Wagner says in discussing the results of these experiments: "Of course these statements of value can only represent approxi-

mately the availability of these nitrogenous matters in comparison with nitrate of soda. It would be foolish to attempt a numerical expression which should be absolutely correct in all cases.

"Under conditions more favorable to the decay and nitrification of organic matters, than prevailed in our tests,—if the soil is richer in humus or lime, lighter, warmer, etc., or if a crop is grown which has a longer period of growth and with it a greater capacity for assimilating nitrogen—then the above figures will be somewhat higher, and on the other hand (under less favorable conditions), lower."

Recent experiments show that calcium nitrate and calcium cyanamid are about equal to ammonium sulphate in availability.

The results of the vegetation tests of the Connecticut Experiment Station show the following availability for different nitrogenous materials.[35]

	Experiments of 1894	Experiments of 1894 aud 1895	Experiments of 1894, 1895 and 1896
Nitrate of soda	100	100	100
Collier castor pomace	90	83	77
Cotton-seed meal	87	79	74
Red seal castor pomace	73	73	70
Linseed meal	74	72	70
Dried blood	79	72	68
Dry fish	69	69	69
Dissolved leather	76	70	65
Horn and hoof	77	67	67
Tankage	73	64	61
Steamed leather	8	10	13
Roasted leather	9	10	9
Raw leather	2	2	2

"The availability of the nitrogen of roasted, steamed and raw leather, while not alike in the three years, is so much lower than that of any other materials tested, as to demonstrate that the nitrogen in them is comparatively inert and of little effect unless applied in large quantities.

ALKALINE PERMANGANATE AND PEPSIN AVAILABILITIES.

No.	Material	Nitrogen content			Grams used	Alkaline permanganate availability		Pepsin availability per cent.
		Total per cent.	Ammonia per cent.	Organic per cent.		Organic per cent.	Total per cent.	
1	Dried blood	13.79	0.07	13.79	0.33	66	66	93
2	Dried blood	14.63	...	14.63	0.31	67	67	97
3	Pig blood	13.54	0.68	12.86	0.35	64	66	98
4	Blood flour	14.03	...	14.03	0.32	62	62	98
5	Dried fish	6.93	...	6.93	0.67	68	68	77
6	Dry mixed fertilizer. Nitrogen from No. 2	4.15	...	4.15	1.08	69	69	95
7	Tankage, high-grade	10.23	0.07	10.23	0.44	57	57	79
8	Tankage, high-grade	9.78	0.07	9.78	0.46	59	59	77
9	Hog tankage	5.63	...	5.63	0.80	52	52	58
10	Bone-meal	2.66	...	2.66	1.69	56	56	75
11	Cotton-seed meal	6.40	...	6.40	0.70	46	46	88
12	Castor pomace	4.83	0.32	4.51	0.98	46	50	78
13	Ground tobacco stems	1.65	...	1.65	2.73	12	12	63
14	Scotch hide and hoof meal	14.80	0.14	14.80	0.30	64	64	21
15	Hoof meal	15.15	0.28	14.87	0.30	68	69	28
16	Treated leather, foreign	8.67	0.07	8.67	0.52	41	41	41
17	Treated leather, foreign	8.09	0.07	8.09	0.56	44	44	47
18	Dissolved leather	8.25	1.09	7.16	0.63	43	51	47
19	Raw leather	8.00	...	8.00	0.56	40	40	53
20	Tygert tankage	9.58	0.07	9.58	0.47	52	52	43
21	Solubilized organic nitrogen	7.55	0.25	7.30	0.62	48	49	55
22	Solubilized organic nitrogan	6.58	0.14	6.44	0.70	45	46	60
23	Original nitrogenous manure	7.62	0.41	7.21	0.62	43	46	49
24	Ammoniated manure	8.03	1.04	6.99	0.64	43	51	42
25	Nitrogenous manure	6.75	0.14	6.61	0.68	46	47	65
26	Nitrogenous manure	6.97	0.44	6.53	0.69	49	52	39

Alkaline Permanganate and Pepsin Availabilities.—(*Continued*)

No.	Material	Nitrogen content			Grams used	Alkaline permanganate availability		Pepsin availability Per cent.
		Total Per cent.	Ammonia Per cent.	Organic Per cent.		Organic Per cent.	Total Per cent.	
27	Extracted leather	8.21	....	8.21	0.55	37	37	45
28	Hide and skin	7.83	....	7.83	0.58	44	44	44
29	Treated leather	7.39	0.10	7.39	0.61	45	45	46
30	Treated leather	7.13	0.14	6.99	0.64	46	48	63
31	Muck tankage	2.86	....	2.86	1.57	30	30	—12
32	Illinois humus peat	2.83	....	2.83	1.59	33	33	—22
33	Nitrogenous material, G	3.13	....	3.13	1.44	31	31	— 5
34	Kiln-dried peat, Florida	2.12	....	2.12	2.12	23	23	—36
35	Air-dried peat, Florida	2.07	....	2.07	2.17	23	23	—37
36	Peat, Vermont	1.68	....	1.68	2.68	23	23	—25
37	Peat, treated with sulphuric acid	0.55	....	0.55	8.18	36	36	19
38	Mora meal	2.67	....	2.67	1.69	26	26	46
39	Tartar pomace	4.23	0.23	4.00	1.13	22	26	12
40	Tartar pomace	3.72	0.28	3.44	1.31	26	31	3
41	Tartar pomace	4.54	0.37	4.17	1.08	43	47	29
42	Tartar yeast manure	3.74	0.27	3.47	1.30	32	37	6
43	Tartar yeast mixture	6.51	0.34	6.17	0.73	39	42	36
44	Tartar yeast mixture	4.92	0.25	4.67	0.96	37	41	31
45	Garbage tankage, New York	2.10	....	2.10	2.14	21	21	6
46	Garbage tankage, Chicago	2.26	....	2.26	1.99	23	23	35
47	Beef refuse compound	7.32	2.77	4.55	0.99	15	47	22
48	Ammoniated manure	6.18	0.97	5.21	0.86	34	44	23
49	Patent nitrogenous potash manure	6.33	1.53	4.80	0.94	15	35	12
50	Fillerine	6.28	1.89	4.39	1.03	18	43	14
51	Beet refuse, potash manure	4.47	0.14	4.33	1.04	29	31	43

"The experiments also demonstrate that leather may be dissolved in oil of vitriol so as to make its nitrogen nearly as available to the maize and oat crops as that of tankage. Samples of roasted leather, steamed leather and dissolved leather were prepared each year from a common stock of raw leather, and slight differences in their preparation might explain the differences of availability observed in different years.

"Of the nine materials tested, other than leather, tankage certainly has the lowest nitrogen-availability, ranking 7th, 9th, and 9th, in the three years tests. Regarding the nitrogen-availability of the other organic matters the experiments are not altogether conclusive."

Laboratory Experiments.—Jones[36] determined the availability of the principal nitrogenous organic materials. It will be seen that cotton-seed meal gives low results with permanganate solution due perhaps to the large amount of non-nitrogenous organic matter present.

Vegetation tests were run on four of these materials by Hartwell. His results follow:

Availability by:

	Pot experiment			Alkaline permanganate method		Pepsin
	Barley	Millet	Oats	Organic	Total	
Original nitrogenous manure	52	70	62	43	46	49
Extracted leather	10	49	38	37	37	45
Tartar yeast manure	19	0	38	32	37	6
Patent nitrogenous potash manure	34	39	21	15	35	12

The summary of the results are given in the following table:

AVAILABILITY SUMMARY.

	Material	Average alkaline permanganate availability: Organic Per cent.	Average alkaline permanganate availability: Total Per cent.	Average pepsin availability
1	Dried blood	65	65	97
	Dried fish	68	68	77
	Tankage	56	56	71
	Bone-meal	56	56	75
	Cotton-seed meal	46	46	88
	Castor pomace	46	50	78
	Tobacco stems	12	12	63
	Hoof meal	66	67	25
2	Leather preparations	44	45	49
	Peat	27	27	−23
	Mora meal	26	26	46
	Tartar pomace	33	37	20
	Garbage tankage	22	22	20
	Sugar-beet—gas house refuse	21	42	19
	Fillerine	18	43	14
	Beet refuse	29	31	43

According to Jones: "Briefly reviewing the results as summarized in the above table we have in the first group the probably readily available ammoniates. Excepting the three vegetable ammoniates to which the alkaline permanganate method is not applicable, but whose rank is clearly established by the pepsin figure, we find the permanganate availability running from 55 to 68 and the pepsin from 71 to 97 per cent. It should be noted that pepsin treatment gives a low result, 25 per cent., for hoof meal, against 66 per cent. by the permanganate process. Certain vegetation tests by the Connecticut Experiment Station indicate that the higher figure is possibly more nearly correct.

"The second group, whether of vegetable or animal origin, shows a decided drop in availability percentage by both methods and fall into the questionable class. The leather preparations were mechanically very fine and dry in many instances partially soluble in water. Many of them carried a considerable percentage of ammonia, for which credit is given in the column headed total."

"The inert nature of the nitrogen in peat is well recognized.

Note the low permanganate availability of 27 per cent. and the pepsin figure of minus 25 per cent." Sample No. 37 shows the increase of availability of peat by treating with sulphuric acid.

Recent work performed at the Rhode Island Station shows that the availability of nitrogen as determined by pot experiments closely approximates the availability by the alkaline permanganate method.[1]

Description of Some of the Low Grade Materials.—The author wrote to Mr. Jones for information as to the sources, process of manufacture and composition of some of the materials mentioned in the foregoing tables. In his reply he states: "I have been on the lookout for all kinds of organic ammoniates during the past ten years; I really know very little of the process of manufacture, nor do I know just where you could obtain definite information on the subject. Such notes as I have obtained from the senders of the samples are as follows:

"**Soluble organic nitrogen** is principally made up of hair and wool.

"**Beet refuse compound** contains from one-half to one per cent. of actual potash. It is beet refuse treated with gas waste and has been criticised as containing sulpho-cyanic acid.

"**High grade potash manure,** is a pure vegetable beet refuse containing 6 to 8 per cent. ammonia and 6 to 9 per cent. actual potash and is very soluble.

"**Tartar pomace** or tartar yeast, is a residue of wine lees of France; a pure vegetable compound.

"Another ammoniated manure is described as the *process treated leather* which is mixed with gas ammonia liquor, containing in addition to ammonia upwards of 1 per cent. potash.

"**Fillerine** is a heavy dark purple material containing cyanide.

"**Ordinary treated leather,** is probably leather refuse baked under steam pressure and ground. Many of the other leather preparations may have been otherwise treated to remove most of the tannic acid and render them non-cakable.

"**French mora meal** contains in addition to ammonia, upwards of 3 per cent. potash. Mr. Hartwell of the Rhode Island Sta-

[1] Journal of Industrial and Engineering Chemistry, Aug., 1911.

tion tells me that the tree from which it is derived is a legume, grows in Guiana and Trinidad and has a pod 6 to 8 inches long by 3 inches wide, which contains a single large bean. It is probable that the mora meal comes from this material, although I have seen no positive statement to that effect.

"**Tygert tankage** is a leather preparation which I have always understood was manufactured in the vicinity of Philadelphia and may possibly contain some ordinary tankage.

"Please understand that I do not vouch for the accuracy of the statements above given as I have had to take all of them second hand."

Value of Low Grade Materials.—Raw leather, wool waste, shoddy, hair, etc., may be rendered fairly available as plant food by special treatment, but such treatment usually is expensive and the market value does not always permit it. The standard high grade materials are always to be preferred and these low grade wastes cannot be sold unless they are much cheaper. Hence these low grade substances are usually only partially treated or not at all, so they have very little value as fertilizer and the use of them is liable to cause disappointment and poor yields. They are not always sold alone but are sometimes mixed together. The writer has examined a product imported from Belgium and sold as Foreign Imported Tankage which was made up of shoddy, wool waste, hair, and leather and was only partially treated. Most of the material was in the raw state and in poor mechanical condition; chemical methods showed it to be poor plant food. This material contained about 7 per cent. nitrogen with traces of phosphoric acid. Should any of these low grade substances be used, the purchaser should demand that they be powdered, or ground very fine, in order to give the soil organisms a better chance to decompose them. The purchaser should not expect to get quick results with many of these wastes as some of them, particularly the raw leather, may remain in the ground for two or three years without any apparent change.

NOTE.—Recent experiments show that the wet process of treating low grade materials increases their availability considerably. This process consists of treating fertilizer materials with sulphuric acid and sealing the same in a den or receptacle for a few days.

The Use of Low Grade Materials is Increasing.—The use of these low grade materials seems to be increasing and many manufacturers are using them in their low grade cheap fertilizers which carry low percentages of nitrogen, to a greater or less extent. The writer believes that some of these materials have no doubt been misrepresented to the manufacturers or else they would not use them. In order to insure future business they endeavor to put out fertilizers that will give good crop returns, and by satisfying their formulas with much of this class of material the poor crop returns will surely hurt them in repeating orders.

Some of these materials are said to be used as dryers by the manufacturers (peat and mora meal for example) but analyses of fertilizers containing them often show that the manufacturers counted the nitrogen content in making the fertilizers. Peat to be sure is a valuable filler for fertilizers as in addition to its drying qualities it contains about 30 per cent. of humus, but its nitrogen is not readily available and fertilizers containing it should have their guarantees satisfied by the use of more available substances.

The Nitrogenous Materials to Use.—We have learned that most plants assimilate nitrogen from the soil as nitrate and occasionally as ammonia. We also know that certain organisms in the soil convert the nitrogen from organic sources into ammonia and from ammonia into nitrates. Therefore it is reasonable to suppose that substances containing nitrogen as nitrates are to be preferred for immediate results in plant growth. As ammonia is converted to nitrates in the soil, materials containing nitrogen as ammonia, as ammonium sulphate for example, are less active than nitrate of soda. Again, nitrogen from organic sources is less active than from substances containing nitrogen as nitrates or ammonia, as organic nitrogen must be changed to ammonia and nitrates before being usable, and we would use materials furnishing this form of nitrogen for slower and more lasting results. We have seen that the nitrogen from organic products varies a great deal in the power of giving up or hold-

ing nitrogen. Dried blood and cotton-seed meal, for example, give up nitrogen quicker than tankage and dry ground fish, and these latter substances do not hold nitrogen as long as leather preparations and wool waste. Therefore in selecting the proper nitrogenous material or materials to use we must consider the condition of the soil, climate, locality, kind of crop, etc.

For Immediate Results.—Should immediate results be desired, applications of nitrate of soda, sulphate of ammonia, lime nitrate, or calcium cyanamid should serve the purpose. The locality may prevent the use of organic substances as a certain amount of heat (37° F.) is required for the soil organisms to convert organic nitrogen into nitrates. A wet season checks nitrification and hence nitrate of soda and sulphate of ammonia should give better results than the organic materials.

For Soils Well Supplied and Long Growing Crops.—Should the soil have a sufficient natural supply of organic nitrogen as from some leguminous crop plowed under, etc., perhaps no organic nitrogenous material should be applied and a small application of some one of the mineral salts may suffice to give the crop a start. If the crop is a long growing one, an organic product may prove best, as it gives up its nitrogen in smaller amounts and more slowly than the chemicals and will thus stay with the crop the whole season. Mixtures of mineral and organic materials may sometimes be best so as to enable the plant to get a quick start by supplying immediate food and when this supply is exhausted, to furnish nourishment from the organic sources for the remainder of the season. The fertilizer manufacturers often use two or three different nitrogenous substances of different forms, as nitrate of soda, sulphate of ammonia and cotton-seed meal, in their fertilizers to allow the plant a continual supply of available nitrogen. Mixtures of organic materials of different availabilities may make excellent combinations for certain crops.

For Large Crops and Building up the Soil.—Should a large crop be desired the chemicals and the active organic substances would perhaps be preferable, but should the building up of the soil for some future crop be wished, the less active organic materi-

als would prove more valuable than nitrate of soda, ammonium sulphate, lime nitrate, calcium cyanamid, dried blood, cotton-seen meal, etc., as these materials are all changed to the nitrate form, except nitrate of soda which is already in this form, either immediately or during the season and would in all probability be lost because nitrates do not become fixed in the soil and are readily washed away by heavy rains. The nitrogen in organic materials is not soluble in water to any great extent as is the case with nitrate of soda, sulphate of ammonia, lime nitrate and calcium cyanamid so that the losses by leaching of the former substances are not considerable as compared to those of the latter.

It is evident then that the farmer should select those substances that will give the best results for his conditions and not purchase nitrogenous fertilizer that some neighbor recommends who secured good crops with an entirely different crop and soil, etc.

Statistics.[32]—The principal materials containing nitrogen that were used in the manufacture of fertilizers for 1900 and 1905 follow:

	1900 Tons	1905 Tons
Bones, ammoniates, etc.	168,510	236,906
Tankage, etc	354,075	439,206
Fish products	28,977	58,437
Cotton-seed products	146,488	183,368
Ammonium sulphate	4,120	10,540
Sodium nitrate	17,203	40,234
Potassium nitrate	884	1,160
Total	720,257	969,851

Potassium nitrate, although an excellent source of nitrogen and potash, is usually too expensive to use in commercial fertilizers.

The total ammonia contained in manufactured fertilizers for 1900 and 1905 was distributed as follows:

	1900 Tons	1905 Tons
Bones, ammoniates, etc.	8,931	8,371
Tankage, etc.	20,182	16,690
Fish products	2,811	5,668
Cotton-seed products	9,212	15,036
Ammonium sulphate	1,022	2,614
Sodium nitrate	3,217	7,524
Potassium nitrate	124	162
Total	45,499	56,065
Per cent. increase	23.22	

Nitrogen Removed by Crops.—Some crops do not remove as much nitrogen as others but still these crops may deplete the soil of nitrogen by allowing it to escape in other ways as by leaching and denitrification.

Functions of Nitrogen.—Nitrogen increases growth and defers maturity. In a certain parish in Louisiana where the people were ignorant along fertilizing lines, cotton-seed meal was the only fertilizer known to them. So year after year they applied this fertilizer to their cotton. For the last three years that they practiced this, they produced excellent large cotton plants but the crop did not mature well or produce scarcely any cotton. The people could not understand it. They did not know that cotton-seed meal was a nitrogenous fertilizer nor did they know that nitrogen produced growth. The Experiment Station was called upon to investigate the trouble and as the soil was naturally rich in potash, applications of acid phosphate corrected the condition. The above example shows the results of an excess of nitrogen in producing growth and deferring maturity.

When excessive nitrogen is applied to potatoes it produces a vigorous growth of vines but very few tubers are formed. Should an excess of nitrogen be supplied the small grain crops it would cause them to lodge and produce grain of inferior quality and the excess of the weight of the crop to the weight of the grain would be high. Excessive nitrogen retards the formation of fruit. It produces growth of wood and leaves when the fruit should be forming.

WEIGHTS OF NITROGEN REMOVED BY ORDINARY CROPS IN POUNDS PER ACRE.[37]

Crops	Wt. as harvested	Nitrogen
Meadow hay, 1½ tons	3,000	37.8
Timothy hay, 1½ tons	3,000	28.3
Clover hay, 2 tons	4,000	79.4
WHEAT		
Grain, 25 bushels	1,500	28.3
Straw	2,500	13.6
Total	4,000	41.9
RYE		
Grain, 30 bushels	1,680	28.5
Straw	2,000	9.6
Total	3,680	38.1
OATS		
Grain, 50 bushels	1,600	30.2
Straw	2,100	13.4
Total	3,700	43.6
BARLEY		
Grain, 50 bushels	2,350	46.6
Straw	2,800	13.7
Total	5,150	60.3
CORN		
Kernel, 50 bushels	2,800	46.1
Cobs	700	2.7
Stover	2,300	14.0
Total	5,800	62.8
POTATOES		
Tubers, 200 bushels	14,000	47.0
Haulm (stems)	4,500	21.1
Total	18,500	68.1
SUGAR-BEETS		
Roots, 20 tons	40,000	115.2
Tops	20,000	76.0
Total	60,000	191.2
MANGELS		
Roots, 25 tons	50,000	112.0
Tops	18,500	51.8
Total	68,500	163.8
TURNIPS		
Roots, 20 tons	40,000	70.4
Tops	11,600	49.8
Total	51,600	120.2
SWEDES		
Roots, 16 tons	32,000	61.4
Tops	4,800	28.6
Total	36,800	90.0
Cabbage, 20 tons	40,000	153.6
Onions, 500 bushels	28,500	63.0
Tobacco, leaf	1,500	58.8

When nitrogen is lacking in the soil the plants do not grow so high as when the supply is sufficient. With crops grown on such soils the proportion of grain or seed to the weight of the crop is high. No matter how much phosphoric acid and potash there may be in the soil the crops can only use quantities in proportion to the growth of the plants, and the growth of plants will be in proportion to the nitrogen supply.

Generally speaking an application of a nitrogenous fertilizer will produce increased yields without the application of potash and with an occasional supply of phosphoric acid. The nitrogen produces a better leaf development, a better growth, the color of crops became a darker green, and the crop matures later. Often the supplying of nitrogen alone will increase yields to such an extent that farmers may overate the value of this constituent. On soils that are deficient in organic matter, that have been continually cropped, the need of nitrogen is generally greater than phosphoric acid and potash.

The following table shows the value of nitrogen in increasing yields.

AVERAGE YIELD OF WHEAT—56 YEARS (1852-1907).[9]

Fertilizer	Grain Bushels	Straw Pounds
Unmanured	12.9	1,050
Mineral fertilizers only, no nitrogen	14.8	1,230
Nitrogen only, no minerals	20.5	1,870
Nitrogen and phosphates	23.7	2,280
Nitrogen, phosphoric acid and potash	31.6	3,190

It is seen that the plot receiving phosphoric acid and potash but no nitrogen produced 1.9 bushels more of grain and 180 pounds more straw than the unfertilized plot. The plot that received nitrogen only produced 5.7 bushels more of grain and 640 pounds more of straw than the plot that was supplied with phosphoric acid and potash. Nitrogen and phosphoric acid show a gain over the nitrogen plot and the complete fertilizer gave the best results.

Market gardeners often take advantage of the power of nitro-

gen in the growing of lettuce and similar vegetables. Vegetables grown on soils more than amply supplied with nitrogen produce more delicate and tender vegetables, especially lettuce and cabbage, but they do not stand shipping so well; although better for immediate consumption than vegetables grown on average soils they wilt and spoil quickly and are not popular with the commission houses. The cell walls and tissues are not so strong with crops grown on excessive nitrogen as when not.

Excessive Nitrogen Invites Diseases.—Crops grown on soils that have excessive nitrogen are more suceptible to plant diseases than on average soils. This may be noticed to a limited extent with oats and wheat. When the season is especially favorable to the production of nitrates in the soil during the growing period or when oats and wheat are grown on rich nitrogenous soils rust is more prevalent than usual. Plant diseases due to excessive nitrogen are perhaps more noticeable with crops grown under glass than outside. Most of the soils that are used in hothouses are very rich in nitrogen and the high temperature kept renders nitrification very rapid. The color of the leaves of hothouse crops becomes a darker green when excessive nitrogen is present, the leaves become tender and thin and seem to be easily attacked by certain fungi unless extra precautions are taken. Cucumbers are especially susceptible to disease in the presence of excessive nitrogen.

CHAPTER VII.

PHOSPHATES.

Phosphates are those materials that contain phosphoric acid. The phosphates occur as phosphate of lime, iron and alumina, in which compounds the phosphoric acid is united with lime, iron and alumina respectively. Since the phosphoric acid in fertilizers is derived mainly from phosphate of lime we will limit our treatment of the subject to the important materials composing this group.

The phosphates of lime occur as organic, organic and mineral, and mineral compounds.

Bones.—The chief source of phosphoric acid from the organic phosphates of lime are bones. The composition of bones is variable. The bones from old mature animals are richer in phosphate of lime than bones from young animals. Different bones from the same animal also show a variable composition, as the harder more compact bones are richer in phosphate of lime than the softer, porous ones.

Raw Bone-Meal.—This is the finely ground product derived from raw bones and it contains all the constituents of them. It carries considerable organic matter much of which is in the form of fats, which makes it hard to grind and to handle on the market. The presence of organic matter makes it objectionable. The fatty matter, which slowly decomposes, tends to make this fertilizer very slowly available for plant food and so it is called a slow acting fertilizer. Raw bone-meal usually contains about 19 to 25 per cent. of phosphoric acid and 2 to 4 per cent. of nitrogen, with an average of 22 per cent. of phosphoric acid and 3.5 per cent. of nitrogen.

COMPOSITION OF RAW BONES.[38]

	Per cent.
Moisture	9.90
Organic matter	33.70
Lime phosphate	49.12
Alkaline salts, magnesia, etc	6.18
Insoluble silicious matter	1.10
Total	100.00
Nitrogen	3.76

The phosphates are sold to the trade on the basis of tricalcium phosphate present. To convert tricalcium phosphate to phosphoric acid, multiply by the factor 0.4576 and to get the equivalent of tricalcium phosphate from a given percentage of phosphoric acid, multiply by 2.185.

Steamed Bone-Meal.—Most of the bone sold for fertilizing purposes has been boiled or steamed in the rendering factories to extract the fats and nitrogenous compounds which are used in making soap, glue, and gelatine. The bones are then ground or pulverized and sold as steamed bone-meal, bone-meal and bone-dust. This product is variable in composition, ranging from 17.5 to 29 per cent. of phosphoric acid and 1.5 to 4.5 per cent. of nitrogen. Good clean bone-meal should contain at least 2.5 per cent. of nitrogen and 25 per cent. of phosphoric acid. The treatment of the raw bones affects the final composition of the product (steamed bone-meal); the boiling or steaming reduces the nitrogen content and increases the phosphoric acid.

Steamed bone-meal is a more quickly available fertilizer than raw bone-meal and is therefore better for most crops.

There is a great difference in the steamed bone-meals put upon the market not only in the composition but in the hardness of the product. Steamed bone-meal from some factories is more porous and softer than from others. Some factories put out a product that crumbles easily while others sell meal that is extremely hard.

COMPOSITION OF STEAMED BONE-MEAL.[38]

	Good quality Per cent.	Bad quality Per cent.
Moisture	11.57	3.95
Organic matter	19.01	14.40
Phosphate of lime, magnesia, etc.	60.02	40.32
Sulphate of lime	0.52	35.42
Alkaline salts, carbonate of lime	8.02	4.21
Silicious matter	0.86	1.70
Total	100.00	100.00
Nitrogen	1.60	1.20

Degree of Fineness.—The bones when sold for fertilizing purposes are ground fine and are known as fine ground bone, bone-meal, bone-dust and bone-flour. The mechanical condition of fineness does not affect the composition but increases the availability of the product for plant food. Hence the finer the bones are ground the more valuable they are as quicker acting fertilizers. These products are generally valued according to their degree of fineness and chemical composition. It must be remembered that all bone-meals give up their plant food slowly and are not desirable for immediate results in the production of crops.

COMPOSITION OF RAW AND STEAMED BONE FOR COMPARISON, KROCKER.[38]

	Raw Per cent.	Steamed Per cent.
Moisture	7.50	5.30
Organic matter	38.00	33.40
(= nitrogen)	(4.05)	(3.80)
Phosphoric acid	19.50	22.80
Lime	24.20	27.70
Carbonic acid	4.10	3.80
Iron oxide, magnesia, alkalies, etc.	3.20	3.40
Insoluble matter	3.50	3.60
Total	100.00	100.00

Bone-Black.—In the manufacture of bone-black, the choicest bones are selected, cleaned and dried. They are then put in air-tight vessels, heated and distilled until all the organic or volatile matter has passed off. The product is then ground to a coarse consistency and sold to the sugar refineries for clarifying or decolorizing syrups in the manufacture of white table sugar. After it has served its usefulness in the sugar refineries it is sold for fertilizer. It contains usually about 30 per cent. of phosphoric acid in the form of phosphate of lime. It is a slow acting fertilizer and is not used extensively in this condition.

COMPOSITION OF BONE-BLACK FROM SUGAR REFINERIES.[35]

	1 Per cent.	2 Per cent.	3 Per cent.	4 Per cent.	5 Per cent.	6 Per cent.
Carbon (nitrogenous)	9.74	10.60	12.86	19.64	7.42	10.64
Calcium phosphate	82.80	83.20	81.80	73.20	87.08	80.56
Calcium carbonate	5.92	4.15	2.92	3.18	1.92	4.52
Calcium sulphate	0.67	0.64	0.42	1.12	0.95	2.24
Iron oxide	0.33	0.55	0.67	0.66	0.85	0.72
Silicious matter	0.54	0.86	1.33	2.20	1.78	1.32
Total	100.00	100.00	100.00	100.00	100.00	100.00

AVERAGE COMPOSITION OF BONE-BLACK, KROCKER.[35]

	Per cent.
Moisture	2.350
Carbon	12.388
Lime	38.416
Phosphoric acid	29.690
Carbonic acid	2.400
Sand	13.300
Other matters	1.456
Total	100.00

Bone-Ash.—When bones are burned the remaining product is called bone-ash. It is not manufactured a great deal in this country because of the greater value of bone-black. It is an excellent fertilizer and the only shipments received to-day come from South America where the bones are burned to save freight. In burning bones the nitrogen is driven off, so that bone ash is valuable only for the phosphoric acid it contains. It varies in phosphoric acid content from 30 to 39 per cent. It is used in some countries in the manufacture of fertilizers.

COMPOSITION OF BONE-ASH.[38]

	Commercial bone-ash Per cent.	Pure ox bone-ash Per cent.
Water and carbon	6.70	1.86
Phosphoric acid	33.68	39.55
(= tricalcium phosphate)	(73.52)	(86.34)
Lime	43.37	52.46
Magnesia	1.14	1.02
Iron oxide	0.58	0.17
Carbonic acid, alkalies and substances not determined	4.84	4.43
Silica	9.69	0.51
Total	100.00	100.00

	From shank bone of horse Per cent.	From ox bone Per cent.
Phosphoric acid	40.29	39.81
Lime	55.01	55.43
Magnesia	0.84	0.80
Potash	0.25	0.49
Soda	0.03	0.60
Carbonic acid	2.99	3.52
Sulphuric acid	trace	0.04
Chlorine		0.06
Total	99.41	100.75

Bone Tankage.—This product is composed entirely of animal matter. It is the refuse from slaughter houses and rendering factories and consists of meat, bone, etc. (from which the fat has been extracted), and sometimes a little dried blood. There are many grades of tankage put upon the market. Those tankages coming under the head of bone tankage contain considerable bone and small amounts of meat and sometimes dried blood. The amount of phosphoric acid in tankage varies with the bone content. The more bone present the higher is the percentage of phosphoric acid. The bone tankages range from 11½ per cent. to 20 per cent. of phosphoric acid. Those tankages falling below 11½ per cent. of phosphoric acid are discussed under the chapter on nitrogenous fertilizer materials. The phosphoric acid in bone tankages has about the same value as in steamed bone, since both of these products are steamed or boiled to extract the fats, etc. The bone tankages are very popular among farmers in certain sections of this country.

Dry Ground Fish.—This is also an organic source of phosphoric acid from phosphate of lime. The phosphoric acid content depends upon the amount of bones present. This product was described with the fertilizer materials containing nitrogen. Suffice it is to say that dry ground fish carries from 6 to 16 per cent. of phosphoric acid.

AVERAGE COMPOSITION OF ORGANIC PHOSPHATES OF LIME.

	Phosphoric acid Per cent.	Nitrogen Per cent.
Raw bone-meal	22	3.5
Steamed bone-meal	25	2.5
Bone-black	30	—
Bone-ash	36	—
Bone tankage	11.5-20	4-6
Dry ground fish	9	8.5

The phosphoric acid present in raw bone-meal, steamed bone-meal, bone tankage, bone-black, bone-ash and dry ground fish is insoluble in water and slowly available as plant food.

Mineral Phosphates.—These phosphates occur in natural beds in different parts of the world. The following descriptions on the production of phosphate rock for 1908 have been mostly taken from Van Horn's article in the American Fertilizer.

The occurrence of rock phosphates in the United States has a very important bearing upon the agricultural industry, since certain classes of plant life cannot exist without the presence of phosphoric acid in the soil. Growing crops deplete the soil of its phosphoric acid, and if no steps are taken to restore this substance, the soil must eventually become non-productive.

Florida, South Carolina, and Tennessee have for several years been the main sources of phosphate in the United States. North Carolina, Alabama, and Pennsylvania have produced phosphate rock, but never on a large scale, and there is at present no production from these states. In 1900 Arkansas entered the field as a producer, and in 1906 a new field was discovered in Wyoming, Idaho, and Utah.

Phosphate mining began in the United States in 1868 in South Carolina. The existence of the rock had been known since 1837, but the possibilities of its commercial use were not recognized until 1859.

Until 1888 South Carolina enjoyed a monopoly of the phosphate industry of the United States. In that year Florida came forward as a phosphate state, with a production of 3,000 long tons. In 1904 the production surpassed that of South Carolina,

and Florida has maintained its lead up to the present time, perhaps because its rock is richer.

In 1892 phosphate was discovered in Tennessee, and two years later the production from that state was 19,188 long tons. In 1899 Tennessee went ahead of South Carolina, the production from the latter state having decreased steadily since 1893.

Production.—The production of phosphate from South Carolina from the beginning of the industry in 1867 to the year 1888, during which period that state was the only producer, was 4,442,945 long tons, valued at $23,697,019. The following table shows the total production in the United States from 1867 to 1908:

Marketed Production of Phosphate Rock in the United States, 1867-1908, in Long Tons.

Year	Quantity	Value
1867–1887	4,442,945	$23,696,019
1888	448,567	2,018,552
1889	550,245	2,937,776
1890	510,499	3 213,795
1891	587,988	3,651,150
1892	681,571	3,296,227
1893	941,368	4,136,070
1894	996,949	3,479,547
1895	1,038,551	3,606,094
1896	930,779	2,803,372
1897	1,039,345	2,673,202
1898	1,308,885	3,453,460
1899	1,515,702	5,084,076
1900	1,491,216	5,359,248
1901	1,483,723	5,316,403
1902	1,490,314	4,693,444
1903	1,581,576	5,319,294
1904	1,874,428	6,580,875
1905	1,947,190	6,763,403
1906	2,080,957	8,579,437
1907	2,265,343	10,653,558
1908	2,386,138	11,399,124
	31,594,279	$128,715,126

Of this quantity South Carolina has furnished 12,138,454 tons; Florida, 14,087,833 tons; Tennessee, 5,315,422 tons; and other states, 53,570 tons. In twenty-one years Florida has produced more phosphate than has South Carolina in thirty-two years.

PHOSPHATE ROCK MARKETED IN FLORIDA, SOUTH CAROLINA AND TENNESSEE, 1905-1908.
Classified by Grades, in Long Tons.

FLORIDA.

Year	Hard rock		Land pebble		River pebble		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1905	577,672	$2,993,732	528,587	$1,045,113	87,847	$213,000	1,194,106	$4,251,845
1906	587,598	3,440,276	675,444	2,029,202	41,463	116,100	1,304,505	5,585,578
1907	646,156	4,065,375	675,024	2,376,261	36,185	136,121	1,357,365	6,577,757
1908	595,473	4,566,018	1,085,199	3,885,041	11,160	33,480	1,692,102	8,484,539

SOUTH CAROLINA.

			Land rock		River rock		Total	
1905	—	—	234,676	774,447	35,549	103 722	270,225	878,169
1906	—	—	190,180	711,447	33,495	105,621	223,675	817,068
1907	—	—	228,354	883,965	28,867	96,902	257,221	980,867
1908	—	—	192,263	854,837	33,232	135,044	225,495	989,881

TENNESSEE.

	Brown rock		Blue rock		White rock		Total	
1905	438,139	1,509,748	44,031	121,486	689	2,155	482,859	1,633,389
1906	510,705	2,027,917	35,669	114,997	1,303	5,077	547,677	2,147,991
1907	594,594	2,880,904	38,993	142,382	5,025	24,550	638,612	3,047,836
1908	374,114	1,572,525	79,717	299,941	1,600	4,755	455,431	1,877,221

The foregoing tables give the amounts of phosphate rock marketed by Florida, South Carolina and Tennessee classified into grades, for the years 1905-6-7-8.

Exports.—The following table shows the production and exportation of phosphate rock since 1899:

PRODUCTION AND EXPORTATION OF PHOSPHATE ROCK IN THE UNITED STATES, 1899-1908, IN LONG TONS.

Year	Production	Exportation
1899	1,515,702	867,790
1900	1,491,216	619,995
1901	1,483,723	729,539
1902	1,490,314	802,056
1903	1,581,576	785,259
1904	1,874,428	842,484
1905	1,947,190	934,940
1906	2,080,957	904,214
1907	2,265,343	1,018,212
1908	2,386,138	1,188,411
Total	18,116,587	1,692,930

Western Deposits.—Within the last few years a large area of phosphate-bearing rock has been discovered in the western United States. This discovery is of much importance since it opens a new field in an area which is tributary to the great agricultural region of the middle west. The phosphate occurs over a considerable area in southeastern Idaho, southwestern Wyoming, and northeastern Utah. It is found in rocks of "upper carboniferous" age in a series of shales and limestones, 100 feet thick, within which are several beds of phosphate rock ranging in thickness from a few inches to 10 feet. At the base of the series is a limestone, and 6 to 8 inches of soft brown shale separates this from the principal phosphate bed, which is 5 to 6 feet thick. This phosphate bed is high in phosphoric acid. There are in the series several beds ranging from a few inches to 10 feet in thickness, and separated by thin beds of limestone or shale. Usually one and sometimes two of these beds at a given section are workable, and probably some of the others will eventually be mined. The lime phosphate content in the workable beds varies from 56 to 80 per cent., with an average of 72 per cent.

WORLD'S PRODUCTION OF PHOSPHATE ROCK, 1905—1907, BY COUNTRIES, IN METRIC TONS.

Country	1905		1906		1907	
	Quantity	Value	Quantity	Value	Quantity	Value
Algeria	334,774	$1,225,126	333,531	$965,600	373,763	$2,142,352
Aruba (Dutch West Indies)	23,307	42,188	26,138	*	†	——
Belgium	193,305	332,292	152,140	282,612	†	——
Canada	1,338	8,876	521	4,024	748	6,018
Christmas Island (Straits Settlements)	99,519	*	92,010	*	†	——
France	476,720	2,093,118	469,408	1,872,000	431,237	1,876,736
Norway	2,522	33,768	3,482	46,524	†	——
Spain	1,370	7,295	1,300	7,592	——	——
Tunis	521,731	1,812,493	796,000	2,304,400	1,069,000	*
United Kingdom	——	——	——	——	43	224
United States	1,978,345	6,763,403	2,114,252	8,579,437	2,301,588	10,653,558

* Value not reported. † Statistics not yet available.

Development and Production.—The newness of the field, the lack of transportation facilities, and the high freight rates have prevented the development of this phosphate territory to any great extent, although there have been some shipments from Montpelier, Idaho, in the last three years.

This field embraces the largest area of known phosphate beds in the world, and at some future time it will doubtless furnish a large part of the world's production of commercial fertilizer. The development of intensive farming as a result of the reclamation of arid lands in the west will afford an increasing home market.

Available Phosphate Deposits.—The known phosphate deposits of the United States are distributed principally among four localities: (1) along the west coast of Florida, running back 20 to 25 miles inland; (2) along the coast of South Carolina, extending 6 to 20 miles inland; (3) in central Tennessee; and (4) in an area comprising southeastern Idaho, southwestern Wyoming, and northeastern Utah. In addition to these areas, some deposits occur in north-central Arkansas, along the Georgia-Florida State line, and in North Carolina, Alabama, Mississippi, and Nevada, but these are mainly of low grade and not utilized at the present time. The three important deposits first mentioned have been worked from ten to thirty years; the fourth is a new field which has as yet had but a small output.

Estimated Life of United States Phosphate Deposits.—The rate of increase in production for the last twenty years has been 117 per cent. for each decade. Assuming that this rate of increase will continue, it will require but a comparatively short time to exhaust the available supply of phosphate rock in the United States. The annual production, at the stated rate of increase, will be approximately 17,000,000 tons in 1932.

It is hardly probable that the rate of increase in production will be so great as for the last decade, since the agricultural lands of the Middle West do not at present need artificial assistance. But increasing population, with its accompanying intensive farming, will eventually force these states to the use of fertilizing

materials. The reclamation of arid lands in the West will probably postpone the day, but even those lands will early need some assistance to grow the large crops which will be required of them.

Of course the vast amount of low grade rock which is now available will be in reserve, and some time before the exhaustion of the high grade phosphates we shall doubtless have begun to use this rock. The increasing price of the 60 to 80 per cent. phosphate will have a hastening effect on the utilization of the present low grade material. The deposits of Arkansas, Georgia, North Carolina, Alabama, Tennessee, and the West, which run from 30 to 50 per cent. in lime phosphate, will be available to draw upon after the high grade rock is exhausted. This class of deposits, especially in Tennessee and in the Western States, will afford an enormous tonnage, but, based upon present available deposits, the life of the phosphates must at best be a short one.

Foreign Deposits.—Deposits of phosphate rock exist in Algeria, France, New Zealand, Canada, Russia, Spain, Tunis, Belgium, French Guiana, and some of the South Sea Islands. The deposits of France and Belgium are practically exhausted, only those of low grade remaining. Concerning the other countries no information as to reserve tonnage is at hand except for the three South Sea Islands—Ocean, Pleasant, and Makatea. These three islands have deposits which are estimated to aggregate 60,000,000 tons of high grade phosphate rock.

Utilization of the Phosphates.—From the foregoing pages it is evident that the utilization of our phosphate deposits to the best possible advantage is imperative. Our farm lands must be preserved for future generations. The phosphate rock of South Carolina is nearly exhausted; the Florida deposits have probably reached their maximum production; the output of the Tennessee deposits is on the increase, but this field alone would at the present rate of increase in production, last only a few years; there is some phosphate in Arkansas, but it is of low grade; therefore the large deposits of the public land states of the West must be depended upon for the greater supply of phosphate rock in the

future. These Western deposits should be controlled by the government in such a way that only a limited amount may be mined and this amount should be saved for domestic consumption.

It is seen that the most important deposits in this country are in Florida, South Carolina, and Tennessee and that the production in the United States amounts to over two million long tons (2,240 pounds) a year while that of the remaining countries approximates one million tons. A glance at the tables is sufficient to impress one with the magnitude and value of this industry in the United States.

South Carolina phosphates were first put upon the market in 1868. There are two kinds of phosphates found in South Carolina, namely, the land and river phosphates. The land phosphate is mined from the land and is known as land rock, while the river phosphate is obtained by dredging rivers and is called river rock. These phosphates occur in the form of nodules varying in weight from a fraction of an ounce to more than a ton.

Whether the rocks are mined or dredged, they are washed free from the clay and other adhering matter and dried, when they are ready for shipment. When phosphate rock is ground or pulverized it is known as floats, and is used in this form in the middle western states quite extensively. The land rock is light fawn colored; the river rock is black; both are very hard. The South Carolina land rock averages about 50 per cent. tricalcium phosphate, which is equivalent to about 23 per cent. of phosphoric acid, and the river rock runs about 50 to 60 per cent. tricalcium phosphate, which is equivalent to 23 to 27.5 per cent. of phosphoric acid.

Including the year 1908, South Carolina's total production of phosphates was 12,138,454 long tons of rock, of which about one-third was shipped to Europe. The discovery of the Florida phosphates decreased the exportation of those from South Carolina to about 30,000 tons annually, because the Florida phosphates that are exported contain more phosphoric acid and less impurities.

ANALYSES OF SOUTH CAROLINA PHOSPHATES.[35]

	River rock		Land rock	
	Per cent.	Per cent.	Per cent.	Per cent.
Water	1.56	4.07	7.40	10.30
Phosphoric acid	26.89	28.44	26.50	22.06
(= tricalcium phosphate)	(58.70)	(62.09)	(57.85)	(48.16)
Lime	42.28	45.07	37.20	37.24
Iron oxide, alumina, magnesia, carbonic acid	18.47	15.16	16.27	15.45
Silicious matter	10.80	7.26	12.63	14.95
Total	100.00	100.00	100.00	100.00

Florida phosphates occur as soft phosphate, pebble phosphate

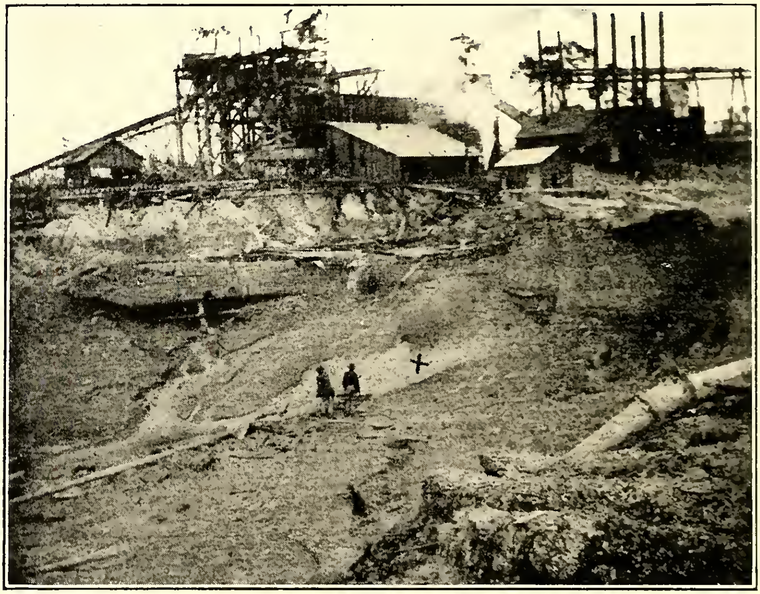

Fig. 15.—Mining phosphate rock, showing the water gun in action.

and boulder or hard rock phosphates. The soft phosphate resembles a whitish clay and generally contains 50 to 60 per cent. of tricalcium phosphate, which is equivalent to 23 to 27.5 per cent.

of phosphoric acid. The hard rock ranges from 60 to 75 per cent. of tricalcium phosphate which is equivalent to 27.5 to 34.3 per cent. of phosphoric acid, although many samples show even a higher content of phosphoric acid. Most all of the high grade phosphates of Florida are exported to Europe where they find a ready market. Florida has put out 14,087,833 tons of phosphate rock from 1888 to 1908.

In some Florida mines a water gun is used for mining the rock. The overburden, as sand, clay, etc., is removed, usually by steam shovels, and then a water gun is employed to shoot into the bank of phosphate rock, sand, etc., which is all washed down into a pool. It is then pumped with centrifugal pumps and elevated into a washer, where the rock is separated from the sand, water, and other foreign material. From there it is conveyed by cars to a bin called the Wet Rock Bin, from which the rock is transferred into large rotatory steel dryers. A flame passes through these cylinders, and as the rock comes out at the lower end it is elevated by a conveyor to a large house called the Dry Bin, from which the shipments are made to the trade.

ANALYSES OF FLORIDA PHOSPHATES.[45]

	Rock Per cent.	Soft Per cent.
Moisture	0.53	4.46
Phosphoric acid	36.72	26.48
Low Grade Soft Phosphates.[44]		
Water	1.77	9.62
Silica	36.90	24.42
Phosphoric acid	21.49	19.93
(= tricalcium phosphate)	(46.91)	(43.55)
Iron oxide	0.44	0.50
Alumina	13.06	17.14
Lime	28.00	——
Aluminum phosphate	——	1.97
Calcium carbonate	——	2.50

Tennessee Phosphates.—These are perhaps the most extensive deposits in the United States that are being worked. Their commercial importance was made known in 1893. The Tennessee

phosphates are known as brown rock, blue rock and white rock. About one-fourth of the high grade Tennessee phosphate is shipped to Europe the remainder being used in this country. The output of Tennessee phosphate has amounted to 5,315,422 tons from 1893 to 1908. The Tennessee rock phosphates are not in favor in Europe because of their high content of iron and alumina oxides, which run from 2 to 4.5 per cent.

The brown rock has been sold more than the blue or white rock.

Analyses of Five Samples of Brown Rock.[39]

	Per cent.	Per cent	Per cent.	Per cent.	Per cent.
Insoluble (silica etc.)	1.31	2 56	1.85	2.16	5.87
Phosphoric acid	36.55	36.55	35.47	35.50	32.85
Phosphate of lime	79.80	79.80	77.45	77.50	71.73
Iron and alumina oxides	2 00	2.48	3.16	3.88	4.52
Carbonate of lime	13.27	12.05	11.46	14.29	9.93
Organic matters and water	3.62	3.11	6.08	3.17	7.95

The blue rock varies from 50 to 70 per cent. lime phosphate or 23 to 32 per cent. phosphoric acid.

Composition of Blue Rock.

	Per cent.
Phosphate of lime	50 to 70
Iron and alumina oxides	2.5 to 5
Silica	1.5 to 5

White Rock.—There are several varieties of white rock varying a great deal in composition.

Analyses of Tennessee White Rock.[39]

	Per cent.	Per sent.	Per cent.	Per cent.	Per cent.	Per cent.
Silica	61.34	49.43	54.30	54.88	50.18	56.46
Lime	20.30	26.40	22.87	22.76	25.57	22.01
Phosphoric acid	12.55	15.12	14.86	15.30	15.21	13.15
Lime phosphate	27.40	33.00	32.45	33.40	33.20	28.60
Lime carbonate	9.75	15.21	9.36	8.23	13.45	11.56

This phosphate, as is shown by the above analyses, contains a great deal of silica and is rather low in phosphoric acid. Not much of this product is consumed. By proper selection of this

grade of phosphate a higher product may be obtained than is represented in the above table.

Canadian Apatite.—This is rock where the phosphate has become crystalline and is known as apatite and is found principally in the provinces of Ontario and Quebec. It is not mined very extensively, only 748 tons being produced for 1907. It is a variable product and contains impurities. The Canadian apatite carries from 75 to 90 per cent. of tricalcium phosphate, which is equivalent to 34 to 41 per cent. of phosphoric acid. Preparing Canadian apatite for the market is a more expensive operation than mining the American phosphates. Apatite is usually considered one of the purest forms of tricalcium phosphate for manufacturing fertilizers.

COMPOSITION OF CANADIAN APATITES.[38]

	Per cent.	Per cent.	Per cent.
Moisture	0.11	0.62	0.10
Phosphoric acid	37.68	33.51	41.54
(= tricalcium phosphate)	(82.25)	(73.15)	(90.68)
Lime	51.04	46.14	54.74
Iron oxide, alumina, etc.	6.88	7.83	3.03
Sandy matter	4.29	11.90	0.59
Total	100.00	100.00	100.00

Rodunda Phosphate.—This phosphate is found on the Rodunda Island.

COMPOSITION OF RODUNDA PHOSPHATE.[38]

	Per cent.	Per cent.	Per cent.
Water	23.23	24.20	27.70
Phosphoric acid	36.95	38.52	19.40
Alumina and iron oxides	36.38	35.33	25.65
Silicious matter	3.44	1.95	27.25
Total	100.00	100.00	100.00

It is seen that this is not a phosphate of lime but a phosphate of iron and alumina. Although the per cent. of phosphoric acid is high, this material cannot be used to manufacture into acid phosphate because of the absence of lime. The gypsum (sulphate

of lime) formed in the manufacture of acid phosphate from phosphate of lime acts as a drier. Rodunda phosphate may be used for crops provided it is well pulverized but it must be considered as slow acting. This product is sometimes called iron and alumina phosphate rock.

Basic Slag.—This is known by several names as iron phosphate, Thomas phosphate powder, odorless phosphate, and phosphate slag. When phosphatic iron ores are used for the manufacture of steel by the basic process, an excess of lime is used which unites with the phosphoric acid and iron and forms a product known as basic slag. There is not much of this product manufactured in this country but the production is large in England, France and Germany. According to Wiley: "The quantity of basic slag manufactured in Germany in 1893 was 750,000 tons; in England 160,000; in France 115,000, making the total production of central Europe about 1,000,000, a quantity sufficient to fertilize nearly 5,000,000 acres. During the year 1907, it is estimated that German agriculture made use of from 1,500,000 to 1,600,000 tons of basic phosphate slags. The total output of basic slag is undoubtedly not far from 2,000,000 tons. The total production of basic slag is therefore approximately one-half of that of crude phosphates."[39]

COMPOSITION OF BASIC SLAG PHOSPHATE.[38]

	Per cent.	Per cent.
Lime	41.54	45.04
Magnesia	6.13	6.20
Ferrous oxide	14.66	11.64
Ferric oxide	8.64	5.92
Manganous oxide	3.81	3.51
Alumina	2.60	1.72
Phosphoric acid	14.32	18.11
Sulphuric acid	0.31	0.41
Sulphur	0.23	0.30
Vanadium oxide	0.29	0.24
Silica	7.40	6.90
Total	99.93	99.99

This product is sold in the form of an impalpable powder which is black in color. The phosphoric acid in basic slag is often

rated as valuable as the phosphoric acid in bone-meal. The composition of this product is variable depending on the amount of phosphoric acid in the iron ore, but it is possible to obtain this product containing 23 per cent. of phosphoric acid, but the lower grades are most common. It averages about 14.20 per cent. of phosphoric acid. On account of the large amounts of iron oxide present, it is not suitable for manufacturing artificial fertilizers.

Leavens says in part the following of basic slag:[40]

1. The phosphoric acid in basic slag is in a form which can not revert or go back to more insoluble forms when mixed with the soil as is the tendency with all superphosphates.

2. The phosphoric acid in basic slag is not washed from the soil by the heavy rains and leached away in the drainage waters as is the case with many other phosphates.

3. Since the phosphoric acid in basic slag never wastes after application to the soil, it follows that basic slag may be applied at any time, either fall, spring, summer, or even in winter without danger of loss.

4. In addition to its high content of phosphoric acid, the large amount of lime in basic slag greatly adds to its value. Instead of having a souring effect on the land, as do superphosphates, basic slag on account of its strong alkaline reaction sweetens acid soils and restores them to a productive condition.

5. Basic slag also contains a considerable amount of magnesia which is extremely valuable in changing crude forms of plant foods in the soil into forms which the plant may take up readily. So powerful is its action in this direction that it is often spoken of as "a chemical plow."

6. The large amount of iron in the basic slag should not be overlooked. "Iron" says Prof Sorauer, in his excellent treatise on the physiology of plants, "is necessary in the building of chlorophyll," the substance that gives the green color to all foliage. "As it is the function of chlorophyll to form new plastic material under the influence of the sunlight, it is natural that the absence of iron, which is shown by the paleness of the leaves, should cause a cessation of assimilation."

7. In addition to all of the above, basic slag commends itself strongly on account of the high degree of availability to plants possessed by its phosphoric acid. While little or none of its phosphoric acid is soluble in pure distilled water, it is soluble in the secretions of the plant roots which feed upon it readily.

Experiments indicate that the total phosphoric acid or basic slag is practically as effective as the available phosphoric acid of acid phosphate.[41]

The average total results show that insoluble phosphoric acid, that is phosphates which have not been treated or dissolved in sulphuric acid (oil of vitriol), have more pounds of crop, both straw and marketable grain, than the phosphoric acid in the soluble and reverted forms; that is, in phosphates which have been dissolved in sulphuric acid.[42]

8. The comparative low cost of basic slag with resulting economy in crop production, is a matter that should appeal to every practical farmer.

Slag phosphate plots produced a greater yield and at a less cost than the average of the soluble phosphoric acid plots and the bone-meal plots. All yields were produced at less cost with slag phosphates than with bone-meal.[42]

9. While basic slag generally should not be mixed with materials containing nitrogen in organic forms such as dried blood, ground bone, dried fish or tankage, many highly desirable and splendid combinations of it with nitrate of soda and potash salts may be made.

By varying the amount of nitrate of soda and potash salts mixed with the slag, fertilizers adapted for use on all of our leading crops may be prepared.

Wheeler states that basic slag is an effective source of phosphoric acid for use upon all kinds of soils, and on account of its lime it is of special promise in the reclamation of exhausted acid soils, particularly such as are rich in organic matter, like many marsh or muck soils.[43]

Basic slag has been found useful for peaches, apples, grapes, oranges, and fruits in general, and for all the cereals. It has also proved very beneficial to clover, alfalfa, and the grasses.

Phosphatic Guanos.—These guanos are of the same origin as nitrogenous guanos. They are the excreta of sea fowls. Before the phosphate deposits were discovered in the United States these guanos were imported into this country and used largely by the manufacturers. All of these guanos originally contained nitrogen. However, the nitrogen, soluble phosphates, and alkalies have disappeared by decomposition of organic matter and leaching of water, so that most of them only contain traces of nitrogen. The phosphoric acid is in the form of tricalcium phosphate and insoluble in water. Some of these guanos contain too much iron and alumina oxides to manufacture profitably. They are not imported into the United States very much now, as many of the deposits are exhausted or else too expensive to compete with our native mineral phosphates.

The following gives a list of the phosphatic guanos that have been used. Those printed in italics are still being shipped.

PHOSPHATIC GUANOS.

	Phosphoric acid Per cent.
Maracaibo, or Monks	42
Raza Island	40
Curacao	40
Baker Island	39
Starbuck	38
Enderbury	37
Californian	35
Aves	34
Fanning Island	34
Howland	34
Sidney Island	34
Mejillones	33
Lacepede Island	33
Malden Island	32
Sombrero	32
Browse Island	31
Huon Island	28
Patos Island	24
Jarvis Island	20
Cape Vert	11

The composition of some phosphatic guanos follow:[38]

	Aves Per cent.	Cape Vert Per cent.	Baker Island Per cent.	Sidney Island Per cent.	Mejillones Per cent.
Water	6.83	15.21	4.71	7.38	8.98
Organic matter	7.03	10.63	6.17	7.29	8.36
Phosphoric acid	33.12	11.37	39.44	34.41	32.59
Lime	42.62		43.01	42.96	38.57
Magnesia	2.03	20.49	2.32	2.03	—
Iron oxide	2.16		0.96 includes sulphuric acid	—	—
Alumina		—		—	—
Potash		—		—	—
Soda		—	—	0.76	—
Sulphuric acid	1.19	—	—	1.63	—
Carbonic acid	3.84	—	0.27	2.64	—
Chlorine	1.07	—	—	0.87	—
Fluorine	—	—	—	0.40	—
Calcium carbonate	—	—	—	—	4.30
Alkaline salts	—	0.92	2.33	—	3.34
Insoluble matter	0.35	41.06	0.79	—	3.86
Nitrogen	traces	0.03	0.34	0.28	—

It should be understood that there are many other phosphates used in other countries but they cannot compete with our mineral phosphates and therefore are not found on the American market.

Classification of Phosphates.—From the foregoing it is shown that there are three classes of phosphates used for fertilizing purposes.

1. Bone phosphates
   - Raw bone-meal
   - Steamed bone-meal
   - Bone-black
   - Bone-ash
   - Bone tankage
   - Dry ground fish

2. Rock phosphates
   - Florida
     - Land pebble
     - River pebble
     - Hard rock
   - South Carolina
     - Land rock
     - River rock
   - Tennessee
     - Brown rock
     - Blue rock
     - White rock
   - Apatite
   - Rodunda phosphate
   - Phosphatic guanos

3. Basic slag phosphates.

Of the bone phosphates, bone-ash is not found much on the

American market and bone-black is usually acidulated (treated with sulphuric acid) before being applied as fertilizer. The production of rock phosphates in the United States has almost entirely discouraged the importation of the mineralized or phosphatic guanos.

Form of the Phosphates.—The phosphoric acid in bone phosphates and rock phosphates is in the form of tricalcium phosphate. Bone phosphates are always as phosphate of lime while rock phosphates contain more or less impurities as iron, alumina and silica. It is customary to apply the name, "bone phosphate of lime," to the phosphate present in rock phosphates, although tricalcium phosphate is the correct name. The phosphoric acid in basic slag is not in the same form as in the other phosphates. It was formerly accepted that the phosphoric acid in basic slag existed as tetra-calcium phosphate, but Hall[9] claims that the phosphoric acid is in the form of double phosphate and silicate of calcium $Ca_3(CaO)\ (Po_4)_2CaSiO_3$.

Availability of the Phosphates.—All of the phosphates are slowly available as plant food and practically insoluble in water. The phosphoric acid in phosphates is not entirely used the first year so that maximum crop returns cannot be expected immediately, but the continued use of phosphates give good results. For quick growing crops the phosphates are not always desirable. The phosphates from bones are perhaps more readily decomposed than the rock phosphates. There is more or less organic matter in bones which decays quite rapidly and attacks the phosphoric acid with which it is closely associated. In the rock phosphates there is no organic decay and the impurities as iron and alumina retard to a certain extent the fermentation and decomposition of the phosphoric acid present. Basic slag phosphate as shown by the statistics in this chapter, is used extensively in Europe. European experiments show that this material is of higher availability than the insoluble bone and rock phosphates.

The nature of the soil has a great deal to do with the availability of phosphates. Soils in good tilth will disintegrate the phosphates more readily than those in poor physical condition. The sandy and gravel soils are liable to give poorer results than

clay soils or soils containing considerable organic matter and potash. Organic matter tends to promote fermentations which attack the phosphates and make them available as plant food, and with the aid of potash, it tends to act upon the lime of the phosphates. The kind of crop also influences the rate of decomposition of phosphates. Some plants are more able to make use of the phosphoric acid of phosphates than others.

The degree in fineness of phosphates influences the readiness with which they are acquired by plants. For this reason these products when used are usually ground very fine, especially basic slag which is ground to a powder. Wagner, a German investigator, obtained the following results with basic slag of various degrees of fineness.

AVAILABILITY OF BASIC SLAG OF DIFFERENT DEGREES OF FINENESS.

Basic slag degree of fineness	Amount per acre in pounds	Barley	Wheat	Flax
Superphosphate	300	100	100	100
Inpalpable powder.....	425	65	61	57
Fine	425	59	61	55
Coarse	875	13	13	16

In the above results the yields from 300 pounds of superphosphate were taken as 100 and the yields from the basic slag were figured on this basis. The results show that the finer the mechanical condition of the basic slag the more available it is. This same condition is true for the other phosphates, as grinding gives a larger area for the soil acids to act upon.

When a farmer wishes to use raw phosphates, the market value per unit of phosphoric acid should govern to a great extent his selection.

CHAPTER VIII.

SUPERPHOSPHATES AND EFFECT OF PHOSPHORIC ACID.

The phosphates mentioned in the previous chapter, with the exception of basic slag, are not always used in the raw condition for fertilizing purposes, but are treated with sulphuric acid in the manufacture of commercial or artificial fertilizers to make the phosphoric acid available; that is, to convert the phosphoric acid into forms that may readily be used by the plant as food.

Manufacture of Super or Acid Phosphate.—The manufacturing of artificial fertilizers began some time after 1840 in which year Liebig, a German scientist, discovered that by adding sulphuric acid (oil of vitriol) to bones the phosphoric acid was made soluble. This discovery paved the way for the manufacture of commercial fertilizers which are sold in such large quantities to-day.

Manufacturing Sulphuric Acid.—The manufacture of superphosphate is rather technical but a knowledge of this important industry may prove of interest. To begin with, the manufacturer purchases pyrites of brimstone and phosphate rock. Pyrites is a compound of sulphur and iron and is obtained from Spain and mines in this country. The pyrites or brimstone are burned in special burners and the sulphurous gases are mixed with nitrous gases obtained from nitrate of soda. These mixed sulphurous and nitrous gases are introduced into large high lead towers and then into lead chambers which are also large and high. Steam is introduced into the lead chambers, mixed with the gases and sulphuric acid is formed which falls to the bottom as a liquid. These lead towers and lead chambers are very costly.

Preparing the Phosphate Rock.—The manufacturer purchases phosphates that contain sufficient tricalcium phosphate to warrant profitable treatment. Phosphates that contain considerable impurities as iron and alumina are avoided. The phosphate rock is broken into small pieces by a machine called the crusher. These small pieces are then ground to a fine powder by special

grinding machinery. This is an important feature in the successful manufacture of superphosphate as the finer the raw product the better is the finished material. When the phosphate is well pulverized the acid can more readily act upon it and so the decomposition is more complete, and an even, high class product is produced. There has been a great deal of money spent in securing machinery that would grind or pulverize phosphates. Some of the phosphates as apatite are extremely hard to pulverize.

Making Superphosphate.—After the phosphate has been well pulverized certain amounts, say 1,000 pounds, of phosphate powder and dilute sulphuric acid (chamber acid) are weighed and dumped into a mixer, which is a cylindrical cast iron container furnished with a revolving shaft on which there are paddles or stirrers, to thoroughly mix or stir the acid and the ground rock. During this mixing great heat is evolved and the sulphuric acid attacks the lime which hold the phosphoric acid and unites with it to form sulphate of lime or gypsum. The phosphoric acid is still held by a small amount of lime. The acid used must contain enough water so that gypsum is formed to insure a dry product. The amount of acid to use depends upon the amount of phosphate of lime and carbonate of lime in the raw product. The acid first acts on the carbonate of lime and cannot act upon the phosphate of lime until the carbonate is decomposed. Therefore the more carbonate of lime present in the raw material the more acid must be used. After the phosphate and acid are thoroughly mixed the mass is dumped into an iron car and the contents tilted into a pit or chamber. This process is repeated many times until the pit or chamber contains many tons of superphosphate. When the mixture of sulphuric acid and powdered rock is first dumped into the pit, it is a semi-liquid mass and dries out in a few days and is ready for shipment. If it is allowed to remain too long in the pit, it becomes caked or hard and must be disintegrated in special machines before being sacked.

Chemistry of the Process.—The phosphoric acid is in the form of tricalcium phosphate in phosphates, or three parts of lime are united with one part of phosphoric acid. When the sulphuric acid is added it attacks the phosphate and dissolves it, setting

free two parts of lime (that were originally combined with the phosphoric acid) which unite or combine with the sulphuric acid forming superphosphate (one lime phosphate or mono-calcic phosphate) and gypsum (sulphate of lime). In other words the phosphoric acid in superphosphate is only combined with one part of lime as the remaining two parts of lime, with which the phosphoric acid was formerly combined, have been set free. From the above it is evident that superphosphate is made up of one lime (mono-calcic) phosphate and gypsum (sulphate of lime). Or the reaction is:

$$\underbrace{(3CaO, P_2O_5)}_{\text{Tricalcic phosphate}} + \underbrace{2\,(H_2O, SO_3)}_{\text{Sulphuric acid}} = \underbrace{(CaO, 2H_2O, P_2O_5)}_{\text{Monocalcic phosphate}} + \underbrace{2\,(CaO, SO_3)}_{\text{Gypsum}}$$

Phosphates of Lime.—In the phosphoric acid fertilizers used there are four different forms of phosphates of lime, all of different availability. These phosphates of lime are known as the insoluble, soluble, reverted, and basic slag forms.

1. **Insoluble Phosphoric Acid.**—The most common form of phosphate of lime is that which is found in bones, mineral phosphates, guanos, etc., and is called insoluble. The lime and phosphoric acid are combined as three parts of lime and one of phosphoric acid. This is called tricalcic, tribasic, bone phosphate and three lime phosphate. We may represent this form as follows:

$$\left.\begin{array}{l}\text{Lime}\\\text{Lime}\\\text{Lime}\end{array}\right\}\ \text{Phosphoric acid}$$

This is the most insoluble form of phosphate of lime and is called insoluble phosphoric acid.

2. **Soluble Phosphoric Acid.**—When insoluble phosphate of lime is acted upon by sulphuric acid, two parts of lime are replaced by two parts of water and soluble phosphate of lime is formed. This soluble phosphate is called super or acid phosphate and is a saturated compound. It is also known as monobasic, monocalcic, and one lime phosphate.

This compound may be graphically represented as:

$$\left.\begin{array}{l}\text{Lime}\\\text{Water}\\\text{Water}\end{array}\right\}\ \text{Phosphoric acid}$$

This form is entirely soluble in water and readily available as plant food. It is the highest valued form of phosphate of lime and is called soluble phosphoric acid.

3. **Reverted Phosphoric Acid.**—Between the soluble and insoluble phosphate of lime there is another form known as reverted, citrate soluble, dicalcic, and two lime phosphate, in which there are two parts of lime and one part of water as represented:

$$\left.\begin{array}{l}\text{Lime}\\\text{Lime}\\\text{Water}\end{array}\right\}\ \text{Phosphoric acid}$$

The name reverted is applied to this form of phosphate of lime because it is formed by reversion or retrograding of some of the soluble towards the insoluble. This form is not as soluble as the soluble phosphoric acid and is more soluble than the insoluble form. It is insoluble in water, but the weak acids of the soil render it favorable for plant food. The sum of the soluble and the reverted is called *available,* because both forms may be used by plants.

4. **Basic Slag Phosphate.**—It used to be accepted that the three forms just described were the only forms of phosphoric acid. However, the phosphate of lime in basic slag is in another form. It was supposed that one part of phosphoric acid was combined with four parts of lime, and in this form it was known as tetracalcic, tetrabasic, and four lime phosphate.

$$\left.\begin{array}{l}\text{Lime}\\\text{Lime}\\\text{Lime}\\\text{Lime}\end{array}\right\}\ \text{Phosphoric acid}$$

Recently, however, there seems to be some uncertainty as to whether or not the phosphoric acid in basic slag exists as tetracalcic phosphate of lime. Hall says: For example, basic slag is found to be readily attacked by a solution of carbon dioxide or other very weak acid; a much larger proportion of phosphoric acid goes into solution than would be the case with an equally fine ground sample of tricalcium phosphate containing the same amount of phosphoric acid. Nearly the whole of the phosphoric acid in basic slag also goes into solution when it is shaken with an

alkaline solution of ammonium citrate, in whch tricalcium phosphate is not very soluble. The analysis of certain flat square plate crystals, occasionally found in cavities in the balls of slag proved them to consist of a tetrabasic phosphate of calcium of the formula $(CaO)_4P_2O_5$, the molecule of phosphorus pentoxide being combined with four molecules of lime instead of with three as in ordinary calcium phosphate. To this tetrabasic phosphate of lime the properties of basic slag have usually been ascribed, it is supposed to be readily acted upon by carbon dioxide with the formation of calcium carbonate and dicalcium phosphate, and as this latter phosphate is readily soluble in water containing carbonic acid, the availability of the basic slag is accounted for.

But it is by no means certain that this association of tetracalcium phosphate with basic slag is correct. In the first place, the detailed analysis of the basic slag hardly bears out this view: there is more lime than is necessary to make up tetracalcium phosphate even when every allowance is made for silica and sulphur, and the amount of free lime that can be determined is not sufficient to make up the balance. Moreover, the crystals of tetracalcic phosphate are only to be found in basic slags made from irons poor in silicon; the usual crystals found in the basic slag cavities are long hexagonal needles, pale green or blue in color, of which considerable quantities can be picked out from the cindery portions of the slag. The appearance also of a fractured surface of the ordinary molten parts of the slag would agree much better with a structure built up of such prismatic crystals than of the flat crystals of tetracalcium phosphate. The prismatic crystals, according to Stead, consist of a double silicate and phosphate of lime of the composition $(CaO)_5P_2O_5SiO_2$, and contain about 29 per cent. of phosphoric acid, 11 per cent. of silica, and 56 per cent. of lime. Moreover, when separated from the mass of the cinder, finely ground, and attacked with water charged with carbon dioxide or with very dilute citric acid, the phosphoric acid they contain shows approximately the same solubility as that of the phosphoric acid in an ordinary sample of basic slag, whereas the crystals of tetrabasic phosphate of lime are markedly less soluble. On the whole, it seems more

probable that the typical phosphoric acid compound of basic slag is this $(CaO)_5P_2O_5SiO_2$— and not the tetracalcium phosphate, $(CaO)_4P_2O_5$, especially as there is plenty of other evidence to show how large a part silica will play in bringing phosphoric acid into a soluble state.

Whatever may be the form of combination of the phosphoric acid in basic slag, it is undoubtedly easily attackable by the soil water, so that it is more available to the plant than any of the forms of tricalcium phosphate, though as a rule it falls below superphosphate.[9]

Amounts of Acid to Dissolve Phosphates.—Voorhees states: Mineral phosphates, both because of their hardness and of the presence of other minerals, which are attacked by the acid, are less easily dissolved, and require more acid in proportion to the phosphate present than those from organic sources. They are also less absorbent, preventing the acid from permeating the mass of the material, and hence it is more difficult to secure good condition when sufficient acid is used to dissolve the phosphate. In making superphosphates from these materials, less acid is used than is required to completely dissolve the phosphates, and there is, therefore, always present in them more or less of the insoluble phosphoric acid.

In the case of animal bone, too, less sulphuric acid is used than is required to completely dissolve the phosphoric acid. Otherwise, a gummy, sticky product would result, due largely to the organic matter in the bone. The insoluble phosphoric acid in bone, bone-black, and bone-ash superphosphates is, however, of greater value than the insoluble in the mineral phosphates, for reasons already given.

In superphosphates, too, there is nearly always present a greater or less amount—depending upon the material—of the second form of phosphoric acid, the dicalcic, reverted or retrograde. This form usually exists in the greatest amounts in those made from mineral phosphates, which is believed to be due either to the soluble acting upon the insoluble portions, or to the presence of oxide of iron and alumina, which combine with a portion of

the soluble phosphoric acid. The soluble goes back to the less soluble dicalcic form.[46]

The Reversion of Phosphoric Acid.—Aikman says: A change which is apt to take place in superphosphate after its manufacture is what is known as reversion of the soluble phosphate. Thus it is found that on keeping superphosphate for a long time the percentage of soluble phosphate becomes less than it was at first. The rate at which this deterioration of the superphosphate goes on varies in different samples. In a well-made article, it is practically inappreciable, whereas in some superphosphates, made from unsuitable materials, it may form a considerable percentage. The causes of this reversion are two-fold. For one thing, the presence of undecomposed phosphate of lime may cause it. This source of reversion, however, is very much less important than the other, which is the presence of iron and alumina in the raw material. When a soluble phosphate reverts, what takes place is the conversion of the monocalcic phosphate into the dicalcic.

Wherever reversion is due to the presence of iron and alumina in the raw material, the nature of the reaction is not well understood, and is, consequently, not so easily demonstrated as in the former case. Where iron is present in the form of pyrites, or ferrous silicate, it does not seem to cause reversion. It is only when it is present in the form of oxide (and in most raw phosphatic materials it is generally in this form) that is causes reversion in the phosphate.

Value of Reverted Phosphoric Acid.—The value of reverted phosphate is a subject which has given rise to much dispute among chemists. That it has a higher value than the ordinary insoluble phosphate is now admitted, but in this country (England), in the manure trade, this is not as yet recognized. At first it was thought that it was impossible to estimate its quantity by chemical analysis. This difficulty, however, has been overcome, and it is generally admitted that the ammonium citrate process furnishes an accurate means of determining its amount. Both on the continent and in the United States reverted phosphoric acid is recognized as possessing a monetary value in ex-

cess of that possessed by the ordinary insoluble phosphates. The result is, that raw mineral phosphates containing iron and alumina to any appreciable extent are not used in this country (England), although they do find a limited application in America and on the continent.[24]

Difference Between Phosphates and Superphosphates.—It is customary among some farmers to call every fertilizer a phosphate and among others this name is used for the product—superphosphate. A phosphate is a product containing phosphoric acid as its main ingredient, in the insoluble form, as bone phosphates, rock phosphates and basic slag phosphates. A superphosphate is a fertilizer containing principally soluble phosphoric acid. The phosphates, except basic slag, may be manufactured into superphosphates by the addition of sulphuric acid as previously mentioned in this chapter. Thus we have superphosphates from bones and minerals, as raw bone superphosphate, steamed bone superphosphate, bone-ash superphosphate, bone-black superphosphate, Florida hard rock superphosphate, Florida pebble superphosphate, Florida soft rock superphosphate, South Carolina land rock superphosphate, South Carolina river rock superphosphate, Tennessee brown rock superphosphate, Tennessee blue rock superphosphate, Tennessee white rock superphosphate, etc. Of course all of these superphosphates will not contain the same amounts of soluble phosphoric acid, as the mode of manufacture and content of phosphoric acid in the raw products determine this. A superphosphate made from bone-black containing 30 per cent. of phosphoric acid will be richer in soluble phosphoric acid than one made from South Carolina land rock running 23 per cent. of phosphoric acid. Bone-black and bone-ash because of their higher phosphoric acid contents make richer superphosphates than those manufactured from most of the mineral phosphates.

Some Names Applied to Superphosphates.—Acid phosphate, dissolved bone, dissolved bone-black and dissolved bone-ash are names that are used indiscriminately by the trade. A manufac-

turer may call a product made from rock phosphate, "dissolved bone," and sell it under this name. Dissolved bone, strictly speaking is a dissolved bone superphosphate, or a superphosphate made from raw or steamed bones. Dissolved bone-black is a superphosphate manufactured from bone-black. Dissolved bone-ash is a superphosphate made from bone-ash. The superphosphates made from rock phosphates are usually called acid phosphates by the trade, although this latter term is applied to any superphosphate and is perhaps a more common name in the United States than superphosphate. For superphosphates made from ground rock phosphate, acid phosphate is perhaps a more correct name as it is the phosphate acted upon by acid.

Available Phosphoric Acid.—There seems to be a great deal of confusion among farmers over what constitutes available phosphoric acid and this is not to be wondered at when one considers the number of terms applied to reverted and insoluble phosphoric acid. Reverted phosphoric acid is soluble in the weak acids of the soil. The chemist uses a solution called ammonium citrate or citrate, which has a similar action to the weak soil acids, in dissolving out this form of phosphoric acid. For this reason the term citrate soluble is often applied to reverted phosphoric acid. The insoluble phosphoric acid is not soluble in this citrate solution but it is soluble in strong acids; hence the names citrate insoluble and acid soluble are applied to insoluble phosphoric acid.

Reverted phosphoric acid is equivalent to citrate soluble phosphoric acid.

Insoluble phosphoric acid is equivalent to $\left\{\begin{array}{l}\text{citrate insoluble phosphoric acid}\\\text{acid soluble phosphoric acid.}\end{array}\right.$

The sum of the soluble and reverted phosphoric acid is called available phosphoric acid, or the sum of the soluble and citrate soluble phosphoric acid is available phosphoric acid. The farmer often confuses the term acid soluble as belonging to the available phosphoric acid on account of the use of the word soluble. Again, the difference between the total phosphoric acid (which is the sum of the soluble, reverted and insoluble forms) and the insoluble phosphoric acid is available phosphoric acid.

$$\text{Available phosphoric acid} = \begin{cases} \text{soluble + reverted phosphoric acid} \\ \text{soluble + citrate soluble phosphoric acid} \\ \text{total — insoluble phosphoric acid} \\ \text{total — citrate insoluble phosphoric acid} \\ \text{total — acid soluble phosphoric acid.} \end{cases}$$

$$\text{Total phosphoric acid} = \begin{cases} \text{soluble + reverted + insoluble phos. acid} \\ \text{soluble + reverted + acid soluble phos. acid} \\ \text{soluble + reverted + citrate insol. phos. acid} \\ \text{soluble + citrate soluble + insol. phos. acid} \\ \text{soluble + citrate soluble + acid sol. phos. acid} \\ \text{soluble + citrate soluble + cit. insol. phos. acid.} \end{cases}$$

The available phosphoric acid contained in manufactured fertilizers for 1900 and 1905, in short tons, was as follows:[32]

	1900 Tons	1905 Tons
Bones, ammoniates, etc.	16,177	15,162
Tankage, etc.	13,455	11,127
Fish products	1,768	3,565
Cotton-seed products	879	1,100
Phosphate rock (acid phosphate)	246,422	273,241
Total	278,701	304,195

The Difference of the Forms of Phosphoric Acid in Superphosphates.—In the manufacture of superphosphates not all of the tricalcium phosphate is converted into soluble phosphoric acid. The manufacturer generally calculates to add just enough acid to convert most of the phosphoric acid into the soluble form. However he does not wish to add much acid in order to put a profitable marketable product. Hence most of the superphosphates found on the market contain some insoluble phosphoric acid, ranging perhaps from a few hundredths to as high as four per cent. in poor acidulation. This insoluble phosphoric acid in superphosphates is different. That in the bone superphosphates is of more value as regards availability than the insoluble phosphoric acid in the mineral superphosphates. The insoluble phosphoric acid is also of different value in the mineral superphosphates depending upon the nature or purity of the rock from which it was made. However, the insoluble phosphoric acid in super or acid phosphates is generally present in small amounts and would only have to be seriously considered when the acidulation proves insufficient. The soluble phosphoric acid in all sup-

erphosphates is the same, whether the superphosphates are made from bones, bone-ash, bone-black, or any of the mineral phosphates. It is an erroneous opinion among some, that the material from which the superphosphate is made influences the value of the soluble phosphoric acid. Many farmers would rather purchase soluble phosphoric acid as superphosphates manufactured from bones than soluble phosphoric acid from mineral superphosphates. There is not any difference in the soluble phosphoric acid of superphosphates no matter what raw material is used in making it. Of course a dissolved bone superphosphate will perchance give better results than a raw rock superphosphate of equal soluble phosphoric acid composition as the dissolved bone superphosphate will contain in addition to the phosphoric acid, a certain amount of nitrogen; so if we judge the value of soluble phosphoric acid in this way we are assuming an unequal and unfair task.

Some Farmers Favor Bone Superphosphates.—Many farmers seem to be prejudiced against the mineral superphosphates and always demands superphosphates made from bone. Often the price is much higher for the bone superphosphates on account of the greater price bones bring when sold for bone-black, manufacturing interests, etc. These farmers could generally purchase their phosphoric acid more cheaply from mineral superphosphates. Of course when dissolved bone and mineral superphosphates of equal available phosphoric acid content, are offered for the same price, it is more economical to select the dissolved bone; but it is seldom that one can get such a bargain as the dealers in fertilizers always charge for the ammonia content. Generally phosphoric acid can be purchased cheaper from mineral superphosphates than from dissolved bone superphosphates.

Double Superphosphate.—This is sometimes called double phosphate. This double superphosphate is manufactured as follows:

Phosphates are treated with an excess of sulphuric acid (chamber acid) and the phosphoric acid is dissolved out as free phosphoric acid. The fluids, sulphuric acid and phosphoric acid are filtered or separated from the insoluble matter and concentrated. This concentrated solution is then used in dissolving

high grade phosphates and the resulting product is called double superphosphate because the phosphoric acid content is more than double and generally three times as much as in superphosphates. Wiley[39] suggests that superphosphate is a more correct name for this class of material as it is a phosphate acted upon by free phosphoric acid and superior to acid phosphate. Phosphates containing too low a percentage of phosphate of lime for profitable manufacture of acid phosphate may be utilized in obtaining the free phosphoric acid.

Not much double superphosphate is found on the American market but it is quite popular in Germany where it is manufactured principally. Double superphosphates contain about 40 to 45 per cent. of available phosphoric acid. They contain less impurities than acid phosphates. The phosphoric acid is present in the same forms as in acid phosphate, namely as soluble, reverted and insoluble phosphoric acid. Double superphosphates are expensive but sometimes economical to purchase when freight is high.

No Free Acid in Treated Phosphates.—Acid phosphates and double superphosphates when well manufactured do not contain any free acid as all of the sulphuric acid is united with lime and forms gypsum. Of course it is possible for a manufacturer to make a product that will contain free acid, but this is not done and the product delivered to the trade does not contain any free acid.

The Color of an Acid Phosphate.—There seems to be a preference among some for a light colored acid phosphate while others demand a dark colored product. The color and nature of the raw material from which acid phosphates are made determine their final color. The manufacturers in order to satisfy the trade often carry two different colored acid phosphates of the same chemical composition which are made from the same raw product. The dark or black color is obtained by mixing in lampblack when the final product is not sufficiently dark. Some raw materials as bone, bone-black, etc., produce a black superphosphate without the addition of any coloring substance. The color of an acid phosphate does not indicate its fertilizing value.

Average Composition of Superphosphates and Double Superphosphates.

	Total Phos. acid Per cent.	Available Phos. acid Per cent.
Acid phosphate	14	12
Acid phosphate	16	14
Acid phosphate	18	16
Dissolved bone-black	17.5	16.5
Dissolved bone-meal	16.5	12.5
Dissolved bone-ash	28	26
Double superphosphate	48	43

The most common of the above fertilizers found on the American market are the acid phosphates carrying 14 per cent. of available phosphoric acid.

How to Make Superphosphate at Home.—Sometimes farmers live far away from places where fertilizers may be purchased and should such farmers save the bones that accumulate on the farm, superphosphate may be made at home. The process may be conducted as follows; Break up the bones in as small pieces as possible and add one-third their weight of water to them in a long wooden trough lined with sheet lead or with a thick coating of pitch; the lead is better. To the bones and water, add very slowly sulphuric acid (oil of vitriol). This acid must be added very slowly as great heat is evolved on the addition of sulphuric acid to water. The amount of acid to add depends upon its strength or concentration. About one-third the weight of the bones of strong white sulphuric acid or one-half of the brown sulphuric acid should suffice. The whole mass should be thoroughly mixed with a wooden shovel, allowed to stand for an hour and removed to some dry place and stored for two months when it will be ready for the land. If sulphuric acid gets on your clothes it will ruin them and it will burn the skin wherever it touches it.

Amount of Phosphates Used for Manufacturing Fertilizers.—The following table gives the tonnage of bone products, tankage, and rock phosphates used in the manufacture of fertilizers in the United States for 1900 and 1905 in short tons.[32]

	1900 Tons	1905 Tons
Bone products	168,510	236,906
Tankage	354,075	439,206
Phosphate rock	958,802	1,063,195

Phosphoric Acid Removed by Crops.—According to Voorhees;[47] the crops of the United States take away from the soil 7,000,000 tons of 14 per cent. acid phosphate annually. There are also large losses by erosion and drainage. So it is probable that at least 1,000,000 tons of phosphoric acid are required to restore the losses of phosphoric acid annually. Hopkins[19] says: "To restore to the soils of the United States the phosphorus (P) removed by the corn crop alone, would require the annual application of our total annual production of phosphate rock, counting 23 pounds of phosphorus for a hundred-bushel crop of corn, and 2¼ billion bushels as the average corn crop of the United States."

The following table shows the amounts of phosphoric acid removed by some common farm crops.

Grain contains more phosphoric acid than straw and roots take away more than tops. Sugar-beets, mangels, turnips, cabbages and onions take away a great deal of phosphoric acid from the soil.

Amount of Phosphoric Acid in Soils.—The phosphoric acid in soils is generally found in largest amounts in the surface soil and is usually derived from the disintegration of rocks. It is often deficient and many soils show only traces of phosphoric acid. Even fertile soils only contain small amounts of this constituent. Soils average from traces to 0.25 per cent. of phosphoric acid. We may figure that an average soil contains about 3,500 to 4,000 pounds of phosphoric acid per acre. Only a small amount of this is available. Some soils may contain large quantities of phosphoric acid but the poor condition of the soil keeps this locked up so that plants cannot utilize it. Organic matter, lime and good tillage help to increase the available supply of phosphoric acid.

WEIGHTS OF AND PHOSPHORIC ACID REMOVED BY ORDINARY CROPS IN POUNDS PER ACRE.[37]

	Wt. as harvested	Phosphoric acid
Meadow hay, 1½ tons	3,000	13.6
Timothy hay, 1½ tons	3,000	21.0
Clover hay, 2 tons	4,000	22.4
WHEAT		
Grain, 25 bus.	1,500	12.4
Straw	2,500	5.8
Total	4,000	18.2
RYE		
Grain, 30 bus.	1,680	14.8
Straw	2,000	5.4
Total	3,680	20.2
OATS		
Grain, 50 bus.	1,600	11.4
Straw	2,100	6.3
Total	3,700	17.7
BARLEY		
Grain, 50 bus.	2,350	19.2
Straw	2 800	5.4
Total	5,150	24.6
CORN		
Kernel, 50 bus.	2,800	16.40
Cobs	700	0.04
Stover	2 300	8.74
Total	5,800	25.18
POTATOES		
Tubers, 200 bus.	14,000	18.9
Haulm (stems)	4,500	6.8
Total	18,500	25.7
SUGAR-BEETS		
Roots, 20 tons	40,000	25.2
Tops	20,000	23.3
Total	60,000	48.5
MANGELS		
Roots, 25 tons	50,000	29.4
Tops	18,500	16.7
Total	68,500	46.1
TURNIPS		
Roots, 20 tons	40,000	38.7
Tops	11,600	13.2
Total	51,600	51.9
SWEDES		
Roots, 16 tons	32,000	18.4
Tops	4,800	4.9
Total	30,800	23.3
Cabbages, 20 tons	40,000	48.6
Onions, 500 bus.	28,500	32.4
Tobacco, leaf	1,500	10.8

Fixation of Phosphoric Acid.—When soluble phosphoric acid is added to soil it becomes fixed and does not wash out readily. Crawley[48] found that when a fertilizer containing water soluble phosphoric acid was applied to the soil and followed by irrigation, more than one-half of the soluble phosphoric acid stayed in the first inch of the soil, more than nine-tenths remained in the first three inches, and about all of it in the first six inches. Soluble phosphoric acid is added to soils because a better distribution is affected, but Crawley's results show that this form of phosphoric acid does not distribute so readily as has been supposed, even when there are heavy rains or irrigation. The soils Crawley worked on were suitable for fixing phosphoric acid and not so acid as many of our soils.

Experiments conducted at Rothamstead show that phosphoric acid is retained in the surface soil.

Phosphoric Acid Soluble in Five Extractions With One Per Cent. Citric Acid, Compared With That in Manure and Crop.[9]

Phosphoric acid, pounds per acre			
Supplied in manure	Removed in crop	Surplus in soil	Dissolved by 1 per cent. citric acid
——	550	—550	565
3,960	790	3,170	3,000
3,810	1,370	2,440	2,470
3,810	1,520	2,290	2,055
——	555	—555	400
3,390	1,200	2,190	2,315
3,390	1,240	2,150	2,000

The above table shows that the phosphoric acid applied to the soil is all accounted for by the removal of crops and the surplus. It shows that the phosphoric acid did not leach out of the soil. The soils of this experiment were well supplied with carbonate of lime which was favorable to the extraction of the phosphoric acid by the citric acid.

It is generally supposed that soluble phosphoric acid from fertilizers becomes readily distributed and unites with the minerals forming compounds insoluble in water; the phosphoric acid in

soluble phosphoric acid is in a very finely divided state and the distribution takes place before the insoluble compounds are formed. Soils rich in lime readily fix phosphoric acid and a certain amount is probably fixed in combination with iron and alumina. Experiments show that phosphoric acid is not carried away by leaching to any extent. All soils are not of equal fixation value; most soils fix phosphoric acid but some are better equipped to perform this process than others. Clay soils rich in lime fix phosphoric acid very rapidly while soils deficient in lime act much slower in this respect. Sandy and gravel soils, lacking in organic matter and clay, do not fix the phosphoric acid rapidly.

Absorption of Phosphoric Acid.—Joffre states: That contrary to what is usually thought, the combinations soluble in water appear to be absorbed by vegetation. The proportion absorbed is, without doubt, very small, but it may have a very great importance because the absorption takes place at a moment when the plants have used up the material in the seed and have not yet developed sufficiently to evaporate the large quantity of water and to be able thus to extract from the soil the useful substances, difficultly soluble, which there exist.

This theory explains perfectly the results of the remarkable researches of Schloesing and Prunet who have found that, when fertilizers are planted in the rows, they produce greater effects than when they are mixed with the soil. This evidence depends upon the fact that when they are planted in rows, they become soluble less rapidly and the plants thus have more time to absorb the combinations of phosphoric acid soluble in water.

Moreover, in the culture experiment made in pure sand where there was nothing which could produce insolubility of phosphate soluble in water and where it is seen that this body causes an increase in the crops, it is necessary to admit that the combinations of phosphoric acid soluble in water enter into the plant and are assimilated there. I have not said that insoluble phosphate is without utility in agriculture. It produces, indeed, in certain earth effects which are as beneficial as the soluble phosphate, but in the greater part of soils, if it produces an action, this action

is less than that of superphosphates and the inferiority of this action appears to be caused, at least in part, because no portion of it can enter immediately into the plant in a condition of aqueous solution.

To resume, the whole of my experiment seems to make clear that the favorable action of superphosphate is not only caused by a greater dissemination of the combination of phosphoric acid in the arable earth, but that it is also necessary to take into account the absorption in the form of combinations, soluble in water, of a portion of soluble phosphoric acid of superphosphates. If we desire to obtain a maximum result it is necessary to distinguish two sorts of soil; first, the soil analogous to those, of which numerous examples are found in Bretagne, in which insoluble phosphates succeed as well as superphosphates and where it is natural to employ phosphate simply ground. Second, the other soils which are far more numerous and in which the phosphoric acid fertilizers in combinations soluble in water are absolutely indispensable to obtain the maximum effect.[49]

Functions of Phosphoric Acid.—Phosphoric acid hastens maturity of crops. It has a ripening effect and seems to hasten grain and fruit formation; it stimulates root development in young plants. The influence of phosphoric acid on grain formation is shown in the following table.

Effect of Phosphoric Acid on Barley.[9]

	Grain Bushels		Grain to 100 straw		Nitrogen per cent. in grain	
	1893	1894	1893	1894	1893	1894
Ammonium salts	11.6	10.4	85.3	67.5	2.19	1.65
Ammonium salts and superphosphate	18.1	34.9	101.0	77.0	2.13	1.60
Ammonium salts and potash	16.8	17.8	85.9	73.8	2.17	1.61
Ammonium salts, superphosphate and potash	30.8	41.4	102.2	77.7	2.08	1.44

The year 1893 was a particularly dry one and in 1894 there was considerable rain and the season was very wet.

It is seen that the phosphoric acid increases the yield of grain

and of grain to straw. It also decreases the nitrogen in the grain.

The same effect of phosphoric acid is shown on wheat.

EFFECT OF PHOSPHORIC ACID ON WHEAT.[9]

	Grain Bushels	Straw Cwt.	Weight per bushel Pounds	Grain to 100 straw
Wet season, 1879				
Unmanured	4.5	6.7	51.8	42.8
Nitrogen only	4.3	8.5	50.8	33.6
Nitrogen and phosphoric acid	11.1	18.0	54.6	36.2
Nitrogen, phosphoric acid and potash	16.0	27.2	57.8	35.2
Dry season, 1893				
Unmanured	10.7	5.6	62.5	110.3
Nitrogen only	8.4	5.6	59.1	84.4
Nitrogen and phosphoric acid	7.7	6.2	56.4	67.3
Nitrogen, phosphoric acid and potash	16.4	9.7	62.6	98.0

Experiments conducted at the Ohio Experiment Station on a rotation of potatoes, wheat and clover from 1894 to 1908 showed greater yields from phosphoric acid than from nitrogen and potash. The Pennsylvania Experiment Station conducted a rotation from 1885 to 1908 with corn, oats, wheat and hay on four acres of land with similar results and the Iowa Experiment Station found that phosphoric acid increased the yield of clover more than did lime, manure, and potash. Many other experiments have been conducted showing that phosphoric acid helps to increase the yield of grain crops.

Experiments indicate that a better root system is had when phosphoric acid is available to the young plant.

Phosphoric acid helps in transferring substances from the stalks, leaves, and other growing parts to the seed. Certain substances are aided by phosphoric acid by being rendered soluble enough to pass through the plant tissues.

Phosphoric acid helps to build up protein substances in the plant as certain proteid bodies require phosphoric acid for their

complete development. Therefore a lack of phosphoric acid would necessarily cause the plant to suffer.

Crop Returns of Phosphatic Fertilizers.—The Ohio Experiment Station ran an experiment for seven years to find out the crop increase of certain commercial (artificial) fertilizers compared to raw and steamed bone-meal. As we are interested in the latter two products the results are here given for these.

	Increase per acre		
	Corn Bushels	Wheat Bushels	Hay Pounds.
Raw bone-meal	6.40	13.22	1,309
Steamed bone-meal	11.02	14.24	1,300

The bone-meals were applied at the rate of 200 pounds per acre to the corn and wheat, which were grown in rotation, followed by clover for one year. It is evident that the steamed bone-meal gave the better results and at the price of these products the phosphoric acid in the steamed bone-meal was the cheaper.

Hall[9] gives returns from phosphatic fertilizers in the following table.

RETURNS FROM PHOSPHATIC FERTILIZERS.

	1878	1879	1880	1881
	Swedes Tons	Barley unmanured Total produce Pounds	Seeds hay unmanured Pounds	Oats manured Total produce Pounds
Ground rock phosphates	15.0	5,844	3,850	5,911
Raw bone-meal	13.4	6,052	4,150	6,686
Phosphatic guano	15.4	6,016	3,380	6.726
Dissolved rock phosphate	15.8	5,964	4,130	7,696
Dissolved bone-meal	15.1	6,364	4,430	7,460
No phosphate	13.1	5,955	3,350	7,132

The results in the above table show lower yields for the raw products than for those that were treated with acid. It is rather to be expected that the raw materials should give lower

returns because they are slow acting and do not give up phosphoric acid so readily as the superphosphates that contain their phosphoric acid mostly in the soluble form. Considering the price that raw bone-meal carries the results are disappointing, showing that this product cannot be economically purchased for fertilizing purposes. It is to be expected that raw bone-meal on account of the fatty matter should be slowly disintegrated. Steamed bone-meal usually gives good results on certain crops. The returns from raw rock phosphate however deserve consideration as this product can be purchased for about one-half of what acid phosphate costs. For certain crops therefore it is often advisable to use raw rock phosphate finely ground.

Experiments at the Ohio Experiment Station gave favorable results with a combination of ground rock phosphate and stall manure on corn, wheat and clover grown in rotation. In this experiment a comparison was made with mixtures of rock phosphate and manure, and acid phosphate and manure, with the result that the above crops were grown for about one-half the cost with the raw rock phosphate. For quick growing crops acid phosphate is no doubt more satisfactory unless the raw rock phosphate is decomposed and rendered available in some way to satisfy the needs of such crops.

Field Experiments with Nine Phosphates.—The Rhode Island Station started an experiment in 1894 to ascertain the relative values of the different phosphatic fertilizers. Quoting from this work: According to the original plan like money values of phosphate were to be compared, and the applications were made for several years upon that basis. Owing, however, to the widely varying market prices from year to year, it was decided in 1898 to change the plan of the experiment so as to make it a comparison of like amounts of phosphoric acid.

The crops of 1894 and 1895 were Indian corn and oats, respectively. In the autumn of 1895 the land was replowed and seeded to clover and grass, as follows:

	Seed per acre
Timothy	12 quarts
Redtop	6 pounds
Medium red clover	12 pounds

Owing chiefly to the dryness of the soil, a stand of clover was not secured, and medium red clover seed was sown again, the next April, at the same rate.

On account of the fact that some of the phosphates contained soluble phosphoric acid while others were practically insoluble in water, all of the more insoluble phosphates were sown broadcast after plowing, and were then thoroughly harrowed into the soil before seeding. These applications were made sufficiently large to cover the crop requirements during the three years that the land was expected to be left in grass. It was planned to divide the application of soluble phosphates into three parts, one-third to be applied annually as a top-dressing, in the spring, together with the nitrogenous and potassic manures which have been applied annually at like rates to all of the plats in both series. Owing to the change in the plan of the experiment in 1898, the land was left for an additional year in grass. In the spring of 1899 such quantities of phosphates were applied as were supposed, based upon their composition, to equalize the amount of phosphoric acid upon all of the plats. It was discovered, however, in 1902 that the assistant to whom the calculations were intrusted in 1899 omitted to take into account the applications of the insoluble phosphates which had been made in the autumn of 1896, and owing to this oversight the complete equalization of the phosphoric acid was not finally accomplished until the spring of 1902. The total amount of phosphoric acid which was applied per plat (two-fifteenths acre) to all excepting the two check plats, from 1894 to 1902 inclusive, amounted to 98.5 pounds, or to 738.6 pounds per acre. This equals 82 pounds per acre annually, an amount which would be supplied by an annual application of about 360 pounds of fine ground bone or of about 500 pounds of acid phosphate.

The following phosphates were used: dissolved bone-black, dissolved bone, dissolved phosphate rock (acid phosphate), steamed bone-meal, basic slag, raw rock phosphate (floats), iron and alumina phosphate, roasted iron and alumina phosphate and double superphosphate. One ton of air slaked lime was applied

RHODE ISLAND EXPERIMENTS WITH NINE DIFFERENT PHOSPHATES.[19]

Pounds of Produce Harvested on Limed Plots.

Form of phosphoric acid applied	Dissolved bone-black	Dissolved bone-meal	Acid phosphate	Steamed bone-meal	Basic slag meal	Raw phosphate (floats)	Raw redondite	Roasted redondite	No phosphates applied	Double superphosphate
1894 ear corn	451	358	395	266	323	169	144	237	261	—
1894 corn stover	371	272	315	193	242	221	201	193	199	—
1895 oats (grain)	118	96	103	87	94	70	61	41	47	82
1895 oat straw	566	920	619	584	646	480	409	280	437	498
1896 to 1899 hay (total in 4 years)	1,984	1,928	2,021	2,201	2,040	2,053	1,439	1,948	1,574	1,794
1900 ear corn	498	529	550	588	556	576	535	578	526	548
1900 corn stover	492	706	666	752	730	610	652	736	604	686
1901 Crops										
Potatoes	140	171	146	159	136	93	74	132	89	137
Japanese millet (green)	220	244	234	245	240	191	130	233	145	230
Oats (cut and weighed green)	76	82	65	71	78	59	38	70	47	74
Golden millet (green)	210	215	214	198	214	187	154	199	175	203
Soy beans (green)	170	160	160	161	178	141	99	140	102	113
Adzuki beans (green)	143	163	160	176	175	134	116	151	113	160
Peas (picked green)	20.5	22.3	20.3	18.3	17.3	17.8	15.3	21.0	19.8	18.8
Hubbard squash (diseased discarded)	—	—	—	—	—	—	—	—	—	—
Flat turnips (roots)	163	177	115	187	192	121	15	125	9	146
Summer squash	65	50	74	53	52	82	34	70	57	46
Rutabaga turnips (not reported)	—	—	—	—	—	—	—	—	—	—
Cabbage (trimmed heads)	115	153	56	173	213	107	4	89	8	118
Crimson clover (green)	91	109	79	76	82	90	64	81	75	111
Red table beets (roots)	134	136	29	146	189	7	1	26	2	86

RHODE ISLAND EXPERIMENTS WITH NINE DIFFERENT PHOSPHATES.[19]

Pounds of Produce Harvested on Unlimed Plots.

Forms of phosphoric acid applied	Dissolved bone-black	Dissolved bone-meal	Acid phosphate	Steamed bone-meal	Basic slag meal	Raw phosphate (floats)	Raw redondite	Roasted redondite	No phosphate applied	Double super-phosphate
1894 ear corn	370	269	326	226	238	195	146	132	189	—
1894 corn stover	138	183	255	187	197	144	154	128	151	—
1895 oats (grain)	96	101	113	84	91	76	50	53	35	80
1895 oat straw	384	480	797	496	529	444	370	376	286	331
1896 to 1899 hay (total in 4 years)	982	856	895	1186	1319	1056	504	493	255	475
1900 ear corn	383	442	496	489	459	475	382	379	316	356
1900 corn stover	488	522	592	586	588	552	368	368	264	334
1901 Crops										
Potatoes	125	146	148	131	140	128	88	84	57	95
Japanese millet (green)	168	200	213	244	235	239	173	199	118	146
Oats (cut and weighed green)	49	59	44	67	76	55	37	36	19	38
Golden millet (green)	147	214	204	211	190	202	165	185	94	169
Soy beans (green)	122	126	126	129	152	143	110	109	75	102
Adzuki beans (green)	69	151	150	149	133	136	96	86	66	62
Peas (picked green)	22.2	23.5	19.8	20.3	17.8	19.0	7.3	13.0	8.8	15.0
Hubbard squash (diseased discarded)	—	—	—	—	—	—	—	—	—	—
Flat turnips (roots)	162	182	93	161	151	49	3	30	0	8
Summer squash	87	60	72	86	85	69	13	30	4	6
Rutabaga turnips (not reported)	—	—	—	—	—	—	—	—	—	—
Cabbage (trimmed heads)	149	142	48	162	150	39	1	1	0	0
Crimson clover (green)	106	83	91	112	107	83	111	79	50	32
Red table beets (roots)	1	62	4	56	61	0	0	0	0	0

per acre on the limed plots and none on the unlimed plots. Applications of potash salts were made, and nitrate of soda was added to all plots to eliminate the benefit of the nitrogen supplied in the bone-meal and dissolved bone.

The results of this experiment are shown on pages 169-170.

Comments on the Results.—The Rhode Island Experiment Station says of these results: With the pea, oat, summer squash, crimson clover, Japanese millet (on the unlimed land), golden millet, white-podded Adzuki bean, soy bean, and potato (on the unlimed land) floats gave very good results; but with the flat turnip, table beet, and cabbage they were relatively very inefficient, nothwithstanding that much more phosphoric acid had been applied in the floats than in any other of the phosphates.

In the case of the pea, oat, summer squash, crimson clover, Japanese millet, golden millet, cabbage, soy bean, and potato the yields were less on the limed soil with than without the raw Redondite (iron and alumina phosphate). With but one or two exceptions the yields were raised somewhat by its use on the unlimed land.

Concerning the roasted Redondite, liming exerted a most marked influence in increasing its efficiency, a point well shown by the summer squash, crimson clover, Japanese millet, white-podded Adzuki bean, and other plants. There were cases of plants on the unlimed land, as for example with the crimson clover and white-podded Adzuki bean, where the raw Redondite seemed to have exerted a more beneficial influence than after it had been roasted, yet this may have been due to inherent differences in the soil itself.

Nothwithstanding the fairly good effect of roasted Redondite upon many of the crops when used upon limed land, its inefficiency with the beet and cabbage under the same conditions was most striking. Double superphosphate particularly, and in some cases dissolved bone-black and acid phosphate, proved relatively inefficient upon the unlimed land, and a few instances of the same kind were observable even where the land had been limed, particularly in the case of those plants which are liable to

injury upon soil which strongly and intensely reddens blue litmus paper and which is at the same time practically devoid of carbonate of lime.

Double superphosphate seemed to be the least adapted to acid soil of any of the soluble phosphates, namely, the dissolved bone, dissolved bone-black, and acid phosphate.

Finely ground unacidulated steamed bone failed to fully meet the needs of some of the crops in the earlier years, but this condition soon ceased and it has given excellent results for several years, and has shown a much greater efficiency than the floats, even though a much larger quantity of phosphoric acid had already been applied in the latter than in bone.

Basic slag meal has proved throughout to be a highly efficient phosphatic manure. Its relative efficiency has been particularly high where those plants have been grown which are helped by liming. This is doubtless due in part to the fact that it contains far more lime than bone-meal or floats.

The use of fine ground bone, basic slag meal, and floats has tended continually to make the unlimed land more favorable to clover, as is well shown by its appearance only upon those plants of the unlimed series where these phosphates had been used, while it was absolutely lacking where raw and roasted Redondite and the soluble phosphates had been applied. Upon limed land, clover has been uniformly common upon all the plats.

In one or two instances it seemed possible that the nitrogen of the bone and dissolved bone might have been of some avail in raising the yields. In most cases, however, evidence of particular advantage in that respect was lacking, which was doubtless due to the heavy applications of nitrate of soda which were made each year. If bone or tankage (which contains much bone) are to be employed upon neglected land deficient in assimilable phosphoric acid, these experiments suggest the idea of supplementing them to some extent for two or three years with basic slag meal, acid phosphate, dissolved bone, dissolved bone-black, or other soluble phosphate.

Floats can probably be used to best advantage on moist soil

rich in decaying vegetable matter, and for such crops as certain legumes, Indian corn, millet and possibly wheat and oats, which seem far better able to make use of them than certain vegetables. The vegetable growers in the East should not be influenced to use them on account of their reported value on the Illinois black soil of the corn belt, where wheat, grass, clover, and Indian corn are the chief crops, and where the soil conditions are exceptionally favorable to their ready assimilability. Perhaps it may be found that floats can be advantageously mixed with the stable manure which gardeners collect during the winter, but this is a point which needs to be more definitely determined. The fact that phosphoric acid in floats costs less than half what it does in bone makes it most desirable to utilize the former where it can be done to advantage, but the Rhode Island gardener and general farmer will do well to study the foregoing results carefully before employing the floats extensively or depending upon them at the outset, or his bank account may pay the penalty.[50]

These experiments were continued with the results shown on pages 174-175.

Summary.—The Rhode Island Experiment Station makes the following summary: In several cases in the limed series the results were better without than with the raw Redondite.

In the unlimed series neither the raw nor the roasted redondite proved to be of much practical value when used in connection with most of the varieties of plants. The crimson clover, potato, and especially the Japanese millet, oat, and golden millet, furnished, however, some notable exceptions.

Floats gave very good results with the soy bean, peas, crimson clover, mangel wurzel (on limed land), barley (on limed land), potato (on unlimed land), Japanese millet, oat, and golden millet, but they proved highly inefficient especially for the Hubbard squash, rutabaga, crookneck squash, flat turnip, cabbage, mangel wurzel (on the acid unlimed land), tomato, lettuce, New Zealand spinach, and red valentine bean.

As a rule in the unlimed series, especially in the case of plants which are subject to injury by acid soils, double superphos-

RHODE ISLAND EXPERIMENTS WITH NINE DIFFERENT PHOSPHATES.[19]

Pounds of Produce Harvested on Limed Plots.

Form of phosphoric acid applied	Dissolved bone-black	Dissolved bone-meal	Acid phosphate	Steamed bone-meal	Basic slag meal	Raw phosphate (floats)	Raw redondite	Roasted redondite	No phosphates applied	Double superphosphate
1902 soy beans (shelled)	165	176	166	176	179	159	103	148	100	152
1903 Crops										
Green peas (in pods)	29	32	27	29	26	17	11	22	15	29
Hubbard squash	122	113	82	130	114	16	0	36	0	107
Swede turnips (rutabaga)	256	312	270	341	293	110	1	117	16	245
Summer squash	129	113	100	101	96	45	1	51	7	101
Flat turnips (roots)	83	127	112	135	86	41	9	39	5	113
Barley (after flat turnips)	11	10	10	14	16	15	10	15	8	8
Cabbage (trimmed heads)	289	422	308	421	396	78	2	38	1	272
Crimson clover (green)	158	161	151	157	142	118	52	135	68	138
Beets (mangel-wurzel)	328	380	340	447	362	223	36	153	40	145
Potatoes	97	167	138	142	150	91	68	52	53	128
Japanese millet (green)	195	215	221	207	191	173	170	203	127	187
Oats (cut "in the milk")	138	167	161	173	165	147	105	153	96	153
Golden millet (green)	162	177	139	165	148	163	132	159	123	160
Tomatoes (green fruit)	49	66	10	15	31	6	2	7	1	18
Lettuce	26	41	25	32	42	12	4	10	4	20
Spinach (after lettuce)	15	47	39	42	51	14	7	18	8	59
Red beans (shelled)	3.0	2.9	2.9	2.9	3.0	1.9	0.9	1.4	0.9	2.3
Cowpeas (failed)	—	—	—	—	—	—	—	—	—	—
Sweet corn (not reported)	—	—	—	—	—	—	—	—	—	—
1904 oat hay	796	890	860	790	850	676	460	696	500	714

RHODE ISLAND EXPERIMENTS WITH NINE DIFFERENT PHOSPHATES.[19]

Pounds of Produce Harvested on Unlimed Plots.

Form of phosphoric acid applied	Dissolved bone-black	Dissolved bone-meal	Acid phosphate	Steamed bone-meal	Basic slag meal	Raw phosphate (floats)	Raw redondite	Roasted redondite	No phosphates applied	Double superphosphate
1902 soy beans (shelled)	140	161	152	165	164	142	96	115	85	118
1903 Crops										
Green peas (in pods)	15	20	19	21	24	18	8	9	6	12
Hubbard squash	63	99	11	50	69	2	0	0	0	13
Swede turnips (rutabaga)	119	175	107	245	232	58	0	1	1	89
Summer squash	43	92	38	63	87	7	0	3	1	60
Flat turnips (roots)	34	70	39	75	64	7	0	1	0	23
Barley (after flat turnips)	1	2	1	5	9	1	0	0	0	0
Cabbage (trimmed heads)	41	168	29	135	165	0	0	0	0	20
Crimson clover (green)	55	116	130	130	152	98	52	54	34	61
Beets (mangel wurzel)	3	101	8	16	73	0	0	0	0	1
Potatoes	68	143	149	144	92	108	62	24	21	23
Japanese millet (green)	144	223	193	189	177	162	137	146	48	52
Oats (cut "in the milk")	124	156	158	161	161	117	77	70	36	64
Golden millet (green)	143	144	149	153	141	146	109	118	50	82
Tomatoes (green fruit)	9	22	23	14	15	0	0	1	0	0
Lettuce	7	17	6	8	8	1	0	0	0	0
Spinach (after lettuce)	14	19	17	34	24	1	0	0	0	0
Red beans (shelled)	1.4	1.9	1.6	1.9	2.0	0.4	0.5	0.7	0.6	0.5
Cowpeas (failed)	—	—	—	—	—	—	—	—	—	—
Sweet corn (not reported)	—	—	—	—	—	—	—	—	—	—
1904 oat hay	432	630	630	636	740	540	280	290	140	340

phate failed to give good results. The same inferior action, in a less degree, was observed in the case of certain plants both with dissolved bone-black and acid phosphate.

In one or two cases the results with acid phosphate were quite poor even in the limed series, but whether this was incidental or due to the presence of some compound peculiar to this substance which is particularly toxic to certain plants, remains to be determined.

Basic slag meal and fine ground bone proved to be excellent phosphatic manures for acid soil, the former being immediately efficient and the latter becoming so after remaining in the soil for two or three years or long enough for extended decomposition to result.

In employing for the first time either raw or steamed bonemeal on land greatly in need of phosphoric acid, supplementary applications of dissolved bone, dissolved bone-black, or acid phosphate should be repeated for two or three years, after which the bone may be expected to meet the demand, provided the applications of bone are generous and are also continued from year to year.

Farmers who are taking up exhausted land or who are planning to grow crops which do not seem to have great feeding power for phosphoric acid, as was shown, for example, in this experiment, by the cabbage, should be very careful to select fertilizers which contain a large proportion of the phosphoric acid in a soluble condition, that is, as soluble phosphoric acid. They should bear in mind that fertilizers, excepting basic slag meal, containing high percentages of the so-called "available" phosphoric acid, none or practically none of which is soluble or capable of being at once dissolved by water, are not adapted to conditions where the soils lack assimilable phosphorus, nor to plants that are lacking in feeding power for phosphoric acid.

It should be again emphasized that the "available" phosphoric acid, as shown by analysis, is obtained by adding together the soluble and reverted phosphoric acid. Bearing this in mind it will be seen that a fertilizer might be made by using roasted

Redondite as the sole source of phosphoric acid which would contain a high percentage of reverted and available phosphoric acid and but little soluble phosphoric acid. Such a fertilizer if applied to a very acid soil lacking in assimilable phosphoric acid would prove practically worthless for certain varieties of plants. If it is known, however, that the land is but slightly or not at all acid, or if lime or wood ashes have been applied recently, then the danger in using such fertilizers is less than it would be otherwise, particularly if legumes, oats, Japanese millet, golden millet, or other plants are grown which have a great feeding power for phosphoric acid in such combinations; nevertheless, even under such conditions the after effect upon many varieties of plants is far less than with bone, basic slag meal and with superphosphates. It must be evident after a study of the foregoing results, especially when it is stated that fertilizers containing small and even very large amounts of roasted and raw Redondite have been sold in Rhode Island, that a safe course for the farmer is to buy the materials and mix his own fertilizer, or he should have a positive assurance as to the character of the materials entering into the ready mixed goods. If the latter can be secured, then it becomes merely a question of price which shall determine his choice.

The results ought to show that attention must be paid to the kind of crop, the kind of phosphate, and the kind of soil, if one will make sure that the phosphoric acid shall pay proper returns for the money employed in its purchase.[51]

CHAPTER IX.

POTASH FERTILIZERS.

Before the discovery of the potash mines in Stassfurt, Germany, the main source of supply of potash was wood ashes.

History.—The following description tells how the deposits of potash salts were formed.

The Stassfurt salt and potash deposits had their origin,

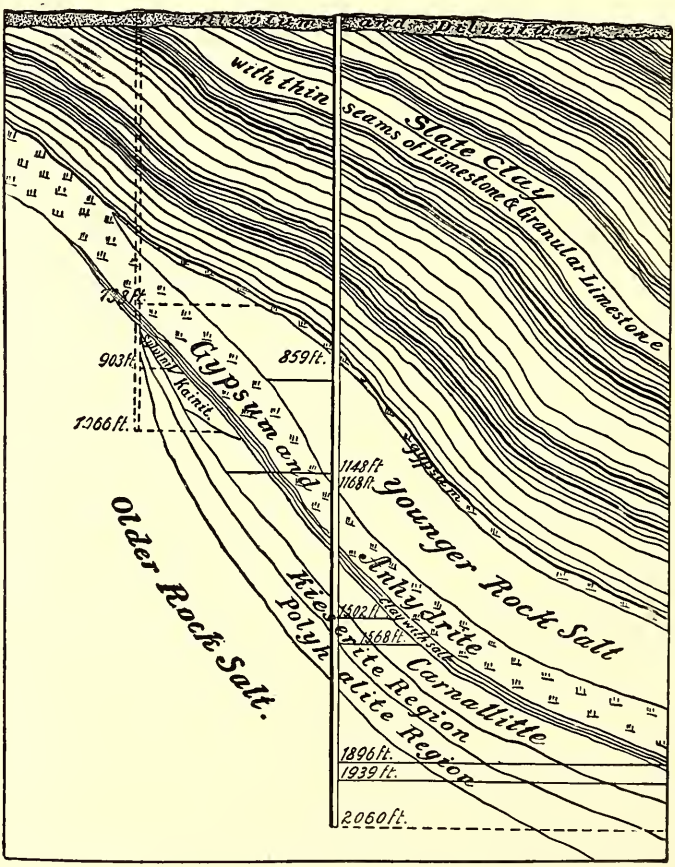

Fig. 16.—Section of potash salt mine shaft.

thousands of years ago, in a sea or ocean, the waters of which gradually receded, leaving near the coast, lakes which still re-

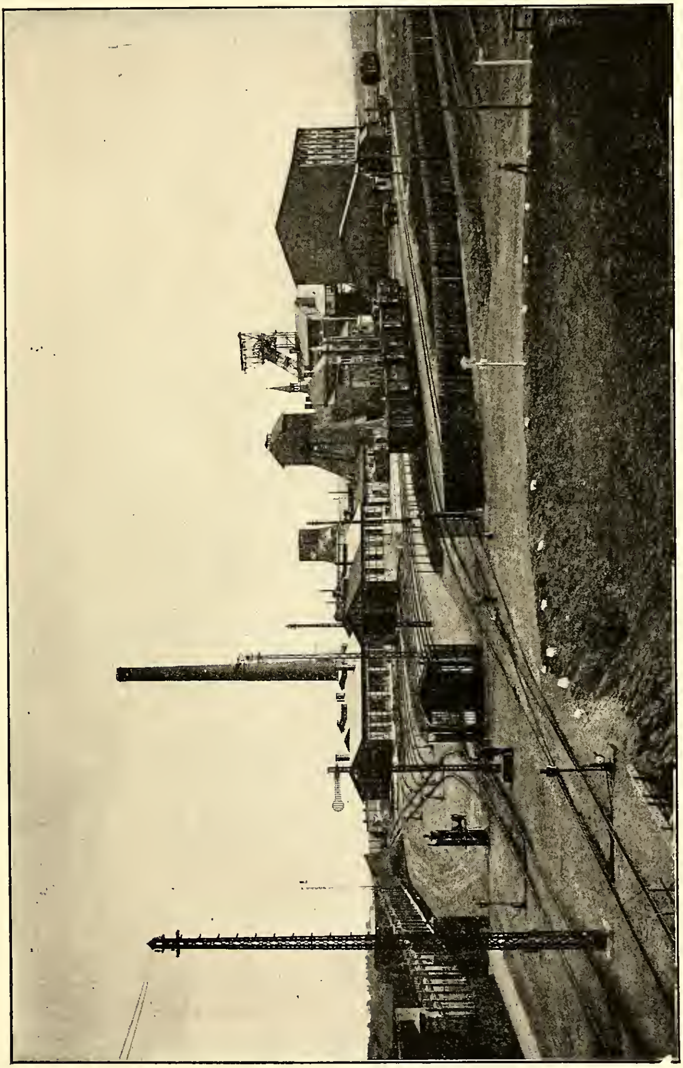

Fig. 17.—Exterior of potash mine.

tained communication with the great ocean by means of small

channels. In that part of Europe the climate was then tropical. and the waters of these lakes rapidly evaporated, but were con-

Fig. 18.—Drilling in potash mine preparatory to blasting.

stantly replenished through these small channels connecting

them with the main body. Decade after decade this continued, until by evaporation and crystallization the various salts present in the sea water were deposited in solid form. The less soluble material, such as sulphate of lime or "anhydrite," solidified first and formed the lowest stratum. Then came common rock salt, with a slowly thickening layer which ultimately reached 3,000 feet, and is estimated to have been 13,000 years in formation. This rock salt deposit is interpersed with lamellar deposits of "anhydrite," which gradually diminish towards the top and are finally replaced by the mineral "polyhalit," which is composed of sulphate of lime, sulphate of potash, and sulphate of magnesia. The situation in which this "polyhalit" predominates is called the "polyhalit region," and after it comes the "kieserit region," in which, between the rock salt strata, kieserit (sulphate of magnesia) is embedded. Above the kieserit lies the "potash region," consisting mainly of deposits of carnallit, a mineral compound of chlorides of potash and magnesia. The carnallit deposit is from 50 to 130 feet thick and yields the most important of the crude potash salts and that from which are manufactured most of the concentrated articles, including muriate of potash.

Overlying this region is a layer of impervious clay which acts as a water-tight roof to protect and preserve the very soluble potash and magnesia salts, which, had it not been for the protection of this overlying stratum, would have been long ages ago washed away and lost by the action of the water percolating from above. Above this clay roof is a stratum of varying thickness of anhydrite, and still above this is a second salt deposit, probably formed under more recent climatic and atmospheric influences or possibly by chemical changes resulting in dissolving and subsequent precipitation of the compounds. This salt deposit contains 98 per cent. (often more) of pure salt, a degree of purity rarely found elsewhere. Finally, above this are strata of gypsum, tenacious clay, sand and limestone, which crop out at the surface.

The perpendicular distance from the lowest to the upper sur-

face of the Stassfurt salt deposits is about 5,000 feet (a little less than a mile), while the horizontal extent of the bed is from the Harz Mountains to the Elbe River in one direction, and from the city of Magdeburg to the town of Bernburg in the other.[52]

It is evident that these deposits are sufficient to supply the world for many centuries.

Discovery.—The Stassfurt deposits, which are the main sources of supply of potash salts for fertilizing purposes, were first used for the rock salt they contained. The presence of potash salts in these mines spoiled the rock salt and it was not until 1857 that the value of these mines was known. In 1862 potash salts were first put upon the market and since that time the use of these salts for agricultural purposes has steadily increased.

Potash Salts Used for Fertilizing Purposes.—The principal potash salts obtained from these mines that are used as fertilizers in the United States are:

1. Kainit
2. Sylvinit
3. Muriate of potash
4. Sulphate of potash
5. Double sulphate of potash and magnesia
6. Potassium—magnesium carbonate.

These products may be classified as crude and manufactured as follows:

Crude salts Natural products	Kainit Sylvinit
Manufactured salts Concentrated salts	Muriate of potash Sulphate of potash Double sulphate of potash and magnesia Potassium–magnesium carbonate.

There are many other salts as carnallit, polyhalit, krugit, hartsalz, sylvin, kieserit and schönit found in these deposits but are not usually sold on the American market.

1. **Kainit** as sold in this country is finely ground, gray-colored and contains small red and yellow particles. This potash salt has been used more extensively in this country than any of the others, but the kainit deposits are gradually becoming ex-

hausted so that it is not so common on our markets as formerly. Kainit is made up of potassium, sodium and magnesium chlorides,

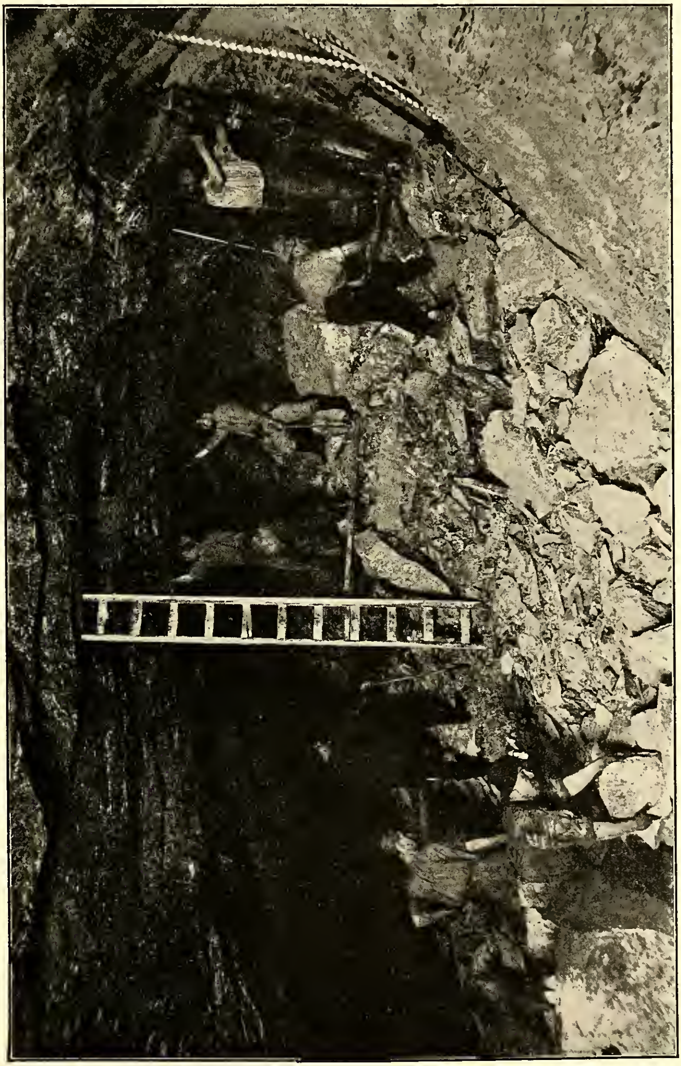

Fig. 19.—Mining kainit.

and potassium, magnesium and calcium sulphates. The potash

is present chiefly as sulphate but on account of the large amounts of sodium and magnesium chlorides present, the potash has the same action as if it were chloride. Kainit usually contains 12 to 12.5 per cent. of potash.

Composition of Kainit.

	Per cent.
Actual potash	12.8
Sulphate of potash	21.3
Chloride of potash	2.0
Sulphate of magnesia	14.5
Chloride of magnesia	12.4
Chloride of sodium	34.6
Sulphate of lime	1.7
Insoluble substances	0.8
Water	12.7

When kainit is kept for a long time it tends to become very hard and compact, due to the presence of sodium and magnesium chlorides. This effect can be eliminated to a great extent by mixing earth with it.

Kainit cannot be used advantageously on crops that are injured by chlorine. Therefore it is objectionable for tobacco. It should be applied to the soil sometime before planting as the chlorides present in this salt are liable to burn or injure the young tender roots. The chlorides of sodium and magnesium often exert a beneficial effect on certain soils because they are easily diffused and thus help to distribute the other ingredients. Kainit is said to check insect damage and prevent certain plant diseases.

2. **Sylvinit.**—This salt when ground is much more red in color than kainit. It is being used more in this country than formerly because of the scarcity of true kainit. It is often sold in the United States by the fertilizer manufacturers under the name kainit. Sylvinit consists chiefly of chlorides; in fact it is composed principally of sodium chloride and potassium chloride.

The sylvinit sold in this country contains from 12.5 to 15.5

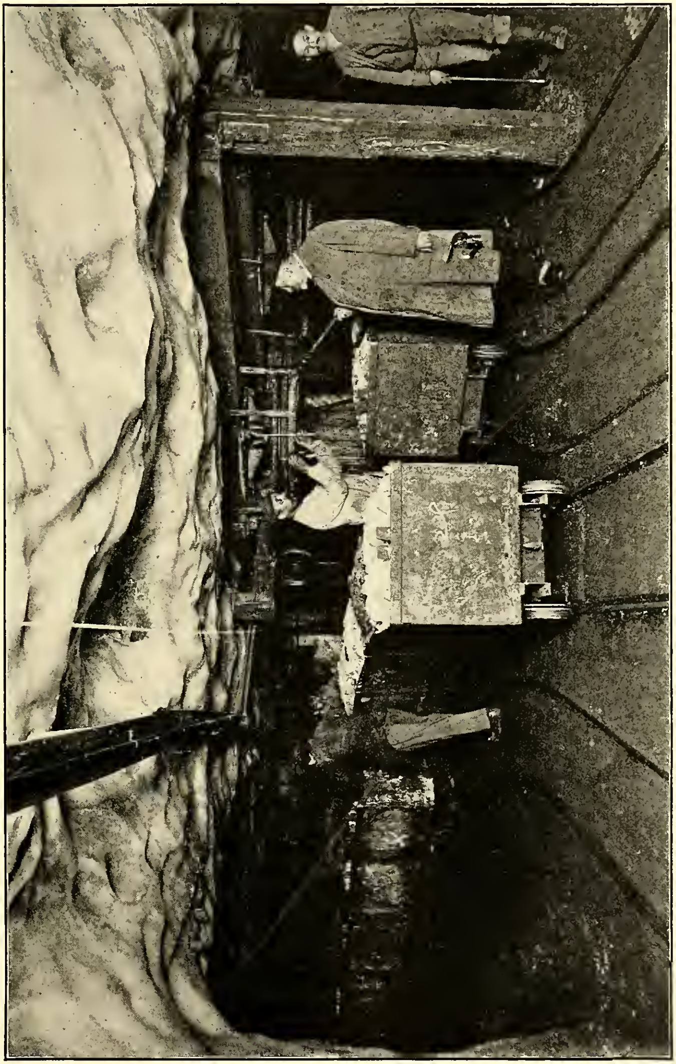

Fig. 20.—Transporting potash salts in the mines.

per cent. of potash. Like kainit it helps to make available other

COMPOSITION OF SYLVINIT.

	Per cent.
Actual potash	17.4
Sulphate of potash	1.5
Chloride of potash	26.3
Sulphate of magnesia	2.4
Chloride of magnesia	2.6
Chloride of sodium	56.7
Sulphate of lime	2.8
Insoluble substances	3.2
Water	4.5

plant food ingredients in the soil, particularly the phosphates, and so it is somewhat of an indirect fertilizer.

3. **Muriate of Potash.**—As has been said, this product is a manufactured one. It is sold in large quantities in this country. The crude salts of the mines are refined, during which process most of the useless impurities are removed, as lime, magnesia, soda, etc. The principal grades of muriate of potash as manufactured are:

Muriate of potash (KCl) Per cent.		Actual potash (K_2O) Per cent.
70 to 75	=	46.7
80 to 85	=	52.7
90 to 95	=	57.9
98	=	62.0

The product sold in the United States usually contains 80 per cent. of muriate of potash which is equivalent to 50.5 per cent. of potash.

COMPOSITION OF MURIATE OF POTASH.

	Grades		
	90 to 95 Per cent.	80 to 85 Per cent.	70 to 75 Per cent.
Actual potash	57.9	52.7	46.7
Sulphate of potash	..	..	1.7
Chloride of potash	91.7	83.5	72.5
Sulphate of magnesia	0.2	0.4	0.8
Chloride of magnesia	0.2	0.3	0.6
Chloride of sodium	7.1	14.5	21.2
Sulphate of lime	..	..	0.2
Insoluble substances	0.2	0.2	0.5
Water	0.6	1.1	2.5

The principal impurity in this product is sodium chloride and the lower grades contain more common salt than the higher

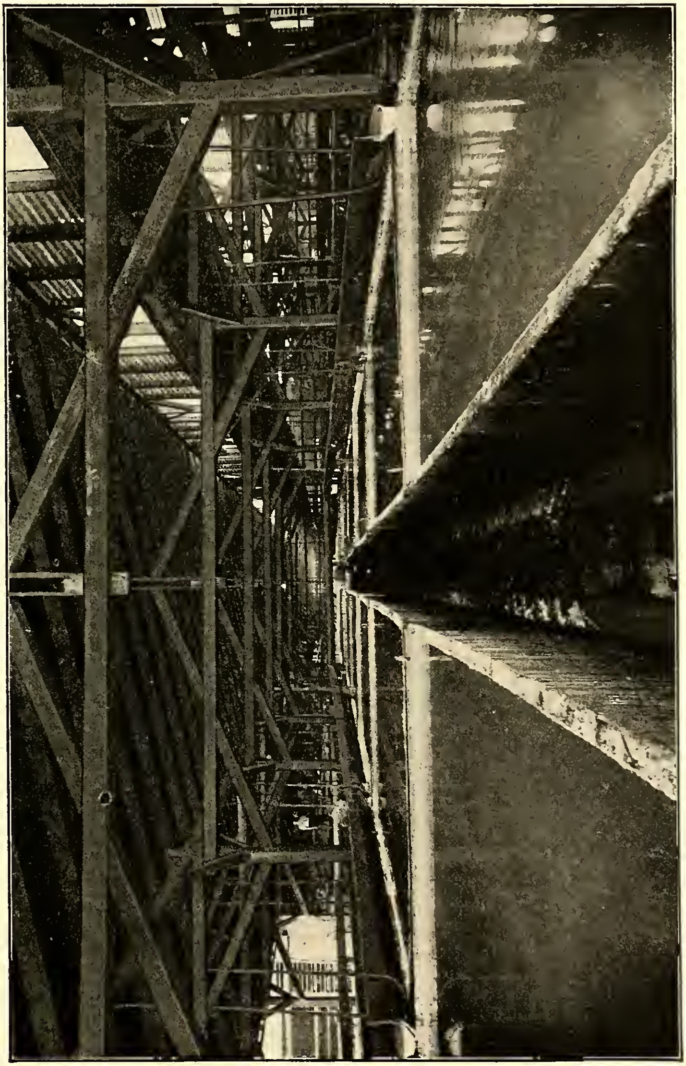

Fig. 21.—Crystallizing vats used in the manufacture of sulphate and muriate of potash.

grades. Muriate of potash is one of the cheapest sources of pot-

ash and can be used for all crops that chlorine does not injure. Tobacco, potatoes, sugar-beets, and oranges are a few crops that will not do well on large quantities of this fertilizer.

4. **Sulphate of Potash.**—This is a yellow, dry, almost powdery substance. It is sold containing 90 to 97 per cent. of sulphate of potash which is equivalent to 46 to 52 per cent. of potash. High grade sulphate of potash containing 50 per cent. of potash is mostly used in America.

Composition of Sulphate of Potash.

	Grade 90 per cent.	Grade 96 per cent.
Actual potash	49.9	52.7
Sulphate of potash	90.6	97.2
Chloride of potash	1.6	0.3
Sulphate of magnesia	2.7	0.7
Chloride of magnesia	1.0	0.4
Chloride of sodium	1.2	0.2
Sulphate of lime	0.4	0.3
Insoluble substances	0.3	0.2
Water	2.2	0.7

Sulphate of potash is more expensive than muriate because the cost of manufacture is more, but it is desirable for tobacco, potatoes, citrous fruits, and other crops that are injured by excessive chlorides. The orange growers of Florida supply potash often as sulphate. The concentrated products, as muriate and sulphate, are often cheaper than kainit and sylvinit per unit of potash. In purchasing the concentrated potash salts there is a saving in freight charges, as it costs as much to ship crude salts as concentrated salts, and the freight for the impurities is saved.

5. **Double Sulphate of Potash and Magnesia.**—This product is somewhat similar in action on crops to high grade sulphate of potash. It contains considerable sulphate of magnesia which is believed to exert a beneficial effect. It usually carries about 26 per cent. of potash. It is not used to any great extent in this country, except by some fruit growers who prefer it to sulphate of potash.

COMPOSITION OF DOUBLE SULPHATE OF POTASH AND MAGNESIA.

	Per cent.
Actual potash	27.2
Sulphate of potash	50.4
Sulphate of magnesia	34.0
Chloride of sodium	2.5
Sulphate of lime	0.9
Insoluble substances	0.6
Water	11.6

Potash Manure Salts.—There are other potash salts that vary from 20 to 30 per cent. of potash called double manure salts and potash manure salts which are not used extensively in fertilizers; although a potash manure salt containing 20 per cent. of potash is sometimes sold which acts like kainit.

COMPOSITION OF POTASH MANURE SALTS.

	Grade	
	20 per cent.	30 per cent.
Actual potash	21.0	30.6
Sulphate of potash	2.0	1.2
Chloride of potash	31.6	47.6
Sulphate of magnesia	10.6	9.4
Chloride of magnesia	5.3	4.8
Chloride of sodium	40.2	26.2
Sulphate of lime	2.1	2.2
Insoluble substances	4.0	3.5
Water	4.2	5.1

The cost of the potash is double sulphate of potash and magnesia and double manure salts is generally more than in kainit, sylvinit, and muriate of potash.

All the salts described are very soluble in water and care should be exercised in their application.

6. **Potassium-Magnesium Carbonate.**—This is a dry, white manufactured product. It is not sold as extensively as kainit, sylvinit, muriate of potash, and sulphate of potash, but it is well liked by tobacco growers. It is also used in Florida on oranges and pineapples. This product is an excellent source of potash for any crops that chlorides prove injurious to. It usually contains from 20 to 25 per cent. of potash in the form of carbonate. On account of its dry nature, and because it does not absorb water from the atmosphere, it is always easy to distribute.

AVERAGE COMPOSITION OF STASSFURT POTASH SALTS IN PER CENT.

Name of salt	Sulphate of potash K_2SO_4	Muriate of potash KCl	Sulphate of magnesia, $MgSO_4$	Chloride of magnesia, $MgCl_2$	Chloride of sodium NaCl	Sulphate of lime $CaSO_4$	Substances insoluble in water	Water	Actual potash, K_2O	
									Average	Guaranteed minimum
A. Crude Salts (Natural Products)										
1. Kainit	21.3	2.0	14.5	12.4	34.6	1.7	0.8	12.7	12.8	12.4
2. Carnallit	—	15.5	12.1	21.5	22.4	1.9	0.5	26.1	9.8	9.0
3. Sylvinit	1.5	26.3	2.4	2.6	56.7	2.8	3.2	4.5	17.4	12.4
B. Concentrated Salts (Manufactured Products)										
a. Sulphates, nearly free from chlorides										
4. Sulphate of potash, 96%	97.2	0.3	0.7	0.4	0.2	0.3	0.2	0.7	52.7	51.8
5. Sulphate of potash, 90%	90.6	1.6	2.7	1.0	1.2	0.4	0.3	2.2	49.9	48.6
6. Sulphate of potash-magnesia	50.4	—	34.0	—	2.5	0.9	0.6	11.6	27.2	25.9
b. Salts containing chlorides										
7. Muriate of potash, 90-95%	—	91.7	0.2	0.2	7.1	—	0.2	0.6	57.9	56.8
8. Muriate of potash, 80-85%	—	83.5	0.4	0.3	14.5	—	0.2	1.1	52.7	50.5
9. Muriate of potash, 70-75%	1.7	72.5	0.8	0.6	21.2	0.2	0.5	2.5	46.7	44.1
10. Potash manure salts, minimum 20% potash	2.0	31.6	10.6	5.3	40.2	2.1	4.0	4.2	21.0	20.0
11. Potash manure salts, minimum 30% potash	1.2	47.6	9.4	4.8	26.2	2.2	3.5	5.1	30.6	30.0

COMPOSITION OF POTASSIUM—MAGNESIUM CARBONATE.[39]

	Per cent.
Potassium carbonate	35 to 40
Magnesium carbonate	33 to 36
Water of crystallization	25
Potassium chloride, potassium sulphate, and insoluble	2 to 3

PRODUCTION OF CRUDE POTASH SALTS, 1905 TO 1909.[32]

Year	Carnallit dz[1]	Kieserit dz	Kainit with hard salt and Schoenit dz	Sylvinit dz	Total dz
1905	22,397,099	27,308	24,055,361	2,306,216	48,785,984
1906	22,631,972	91,905	27,540,215	2,849,435	53,113,527
1907	25,347,888	103,595	27,889,734	3,041,431	56,382,648
1908	27,687,939	184,730	29,215,093	3,052,824	60,140,586
1909	32,807,260	73,878	32,680,871	3,447,493	69,011,539

[1] Dz = 220.47 pounds.

PRODUCTION OF MANUFACTURED SALTS, 1905 TO 1908.[32]

Year	Chloride of potash 80 per cent. dz.	Sulphate of potash 90 per cent. dz.	Sulphate of potash-magnesia 48 per cent. dz.	Potash manure salts dz.	Crystallized sulphate of magnesia dz.	Kieserite in blocks dz.	Calcined ground kieserite dz.
1905	2,547,107	422,204	305,892	2,154,075	7,178	350,025	6,001
1906	2,793,196	511,815	370,907	2,782,850	8,342	294,109	6,318
1907	2,912,476	562,534	315,028	2,862,613	7,881	265,209	4,566
1908	2,885,243	547,511	337,564	3,132,205	6,652	255,325	6,684

IMPORTATIONS OF POTASH SALTS FROM GERMANY TO THE UNITED STATES, 1908-1909, IN TONS.[32]

Year	Hartz salts, Kainet, Kieserit, etc.	Muriate of potash	Sulphate of potash
1908	364,731	100,587	59,869
1909	469,963	132,198	63,845

The following table gives the consumption of potash salts in actual potash, acres of arable land, and the amounts of actual potash used per 100 acres of arable land in the countries enumerated for the year 1900.[39]

CONSUMPTION OF POTASH SALTS IN ACTUAL POTASH.

Country	Potash salts consumed in tons of actual potash (K_2O)	Arable land in acres	Potash salts used per 100 acres arable land in pounds of actual potash (K_2O
	1900	1900	1900
Germany	117,712	86,971,300	298.3
Holland	7,106	5,012,100	312.5
Sweden	8,197	8.622,000	209.5
Scotland	3,370	3,641,200	204.0
Belgium	3,607	5,232,800	151.9
Denmark	1,692	6,305,000	59.1
England	4,020	16,915,400	52.4
Norway	286	1,412,900	44.7
Switzerland	1,026	5,258,700	43.0
United States	66,595	348,212,300	42.2
Finland	382	2,755,100	30.6
Ireland	600	5,322,500	24.8
France	8,229	92,649,800	19.5
Spain	2,428	72,201,100	7.4
Italy	1,380	50,421,000	6.1
Austria-Hungary	2,389	99,416,900	5.3
Portugal	43	11,329,000	0.8
Russia	1,597	515,055,200	0.7

Potash Investigation in the United States.—From the foregoing it is evident that Germany has a monopoly on the mineral potash output of the world and our farmers are dependent on this supply. Recently the American fertilizer manufacturers had some difficulty with their German potash contracts and considerable discussion was entered into before settlement was reached. Because of this trouble our government has appropriated money and placed it under the supervision of the Geological Survey for the purpose of investigating certain western sections of the United States where paying potash deposits are liable to be found. Present reports are quite favorable. Should the Geological Survey succeed in this investigation we will be independent of Germany for our potash and it will be the greatest fertilizer discovery of recent times in the United States.

Potash from Organic Sources.—Most of the potash used in fertilizers is derived from the mineral sources but a small amount

is sometimes purchased in the form of wood ashes, tobacco stems, cotton-seed hull ashes, and beet molasses.

1. Wood Ashes.—Before the discovery of the Stassfurt deposits wood ashes were used more extensively than now and were practically the chief source of potash to be found on the American market. The potash in wood ashes is in a form (as carbonate) which is very desirable for all plants. The product offered to the trade is not uniform as different woods, parts of the same wood as bark, twigs, etc., and methods of handling, all influence the composition. The ashes from soft woods usually contain a lower percentage of potash than the ashes from hard woods. Leached wood ashes naturally carry much less potash than the unleached ashes. Ashes contain small amounts of phosphoric acid and large percentages of lime. They usually contain more or less dirt and moisture which lower the composition. The main source of wood ashes is Canada as not much wood is burned in the United States.

The following compilation made by the Massachusetts Agricultural Experiment Station shows the composition of 97 samples of unleached wood ashes.[53]

COMPOSITION OF UNLEACHED WOOD ASHES.

	Average Per cent.	Maximum Per cent.	Minimum Per cent.
Potash	5.5	10.2	2.5
Phosphoric acid	1.9	4.0	0.3
Lime	34.4	50.9	18.0
Magnesia	3.5	7.5	2.3
Insoluble matter	12.9	27.9	2.1
Moisture	12.0	28.6	0.7
Carbon dioxide and undetermined	29.8	—	—

The analyses of 15 samples from domestic wood fires in New England show the following average.[54]

	Per cent.
Potash	9.63
Phosphoric acid	2.32

The analyses of leached and unleached ashes follow:[39]

	Unleached Per cent.	Leached Per cent.
Insoluble matter	13.0	13.0
Moisture	12.0	30.0
Calcium carbonate and hydroxide	61.0	51.0
Potassium carbonate	5.5	1.1
Phosphoric acid	1.9	1.4
Undetermined	6.6	3.5

In leaching wood ashes the phosphoric acid and potash are principally lost.

Amounts of Ingredients in Different Kinds of Wood Ashes.—The table on page 195 gives the amounts of ingredients in the ashes of several common woods.

Value of Wood Ashes.—From a chemical standpoint the value of wood ashes is represented in the contents of potash, phosphoric acid and lime. Ashes have another value in improving the condition of the soil. They seem to help to conserve moisture, improve the texture of soil and correct acidity, thereby increasing the action of the organisms that promote nitrification. Most soils are benefited by an application of wood ashes. Grasses and legumes especially do well when wood ashes are applied as a top dressing.

2. **Tobacco Stems.**—Wherever cigars, cigarettes, smoking and chewing tobacco are manufactured there are considerable wastes of stems and stalks collected. This material was formerly thrown away or burned. The burning of tobacco wastes caused the nitrogen to be lost. To-day these wastes are saved and used as fertilizer.

Analyses of Tobacco Stems.[55]

	Kentucky stems Per cent.	Connecticut stems Per cent.
Moisture	26.70	13.47
Organic matter	60.18	70.85
Ash	13.12	15.68
Phosphoric acid	0.67	0.53
Potash	8.03	6.41

POUNDS OF INGREDIENTS NAMED IN TEN THOUSAND POUNDS OF WOOD.[39]

	Dogwood (Cormus florida)	Sycamore (Platanus occidentalis)	Post oak (Q. obtusiloba)	Ash (F. Americana)	Red oak (Q. rubra)	Hickory (Carya tomentosa)	White oak (Q. alba)	Magnolia (M. grandiflora)	Georgia pine (P. palustris)	Yellow pine (P. mitis)	Black pine (Picea nigra)	Chestnut (Castanea vesca or sativa)	Old field pine (P. mitis)
Potash	9.02	18.06	16.85	14.94	13.95	13.80	10.60	7.13	5.01	4.54	3.02	2.90	0.79
Phosphoric acid	5.72	9.55	6.96	1.15	5.98	5.83	2.49	3.19	1.24	0.96	0.92	1.09	0.73
Lime	6.41	24.73	35.61	7.60	27.40	18.40	7.85	14.21	18.04	15.16	12.46	7.93	12.12
Magnesia	14.67	0.49	5.28	0.10	3.05	4.86	0.90	2.94	2.03	0.74	0.10	0.34	1.17

THE PURE ASHES OF THE WOODS CONTAIN THE FOLLOWING PER CENTS. OF THE INGREDIENTS NAMED.[39]

	Dogwood	Sycamore	Post oak	Ash	Red oak	Hickory	White oak	Magnolia	Georgia pine	Yellow pine	Black pine	Chestnut	Old field pine
Potash	28.04	23.17	21.92	46.04	24.66	28.60	42.16	19.54	15.35	19.70	14.30	18.10	3.85
Phosphoric acid	8.51	12.23	9.00	3.58	10.55	11.97	9.48	8.75	3.82	4.18	4.33	6.76	4.11
Lime	38.93	31.62	46.39	23.57	48.26	37.94	29.85	38.94	55.24	65.53	58.98	49.18	67.73
Magnesia	6.80	0.62	6.88	0.60	5.38	10.04	3.43	8.05	6.25	3.20	0.50	2.11	6.54

The phosphoric acid content in tobacco stems is rather low and the potash constitutes about one-half of the total ash.

The stalks of tobacco have about the same composition as the stems but the ash is much lower. The Connecticut Experiment Station found the ash to be, on the water free basis, 6.64, 7.00 and 7.46 per cent. on three samples. About 55 per cent. of the ash was found to be as potash and 6.3 per cent. as phosphoric acid.

AVERAGE COMPOSITION OF TOBACCO STEMS AND STALKS.

	Stems Per cent.	Stalks Per cent.
Notrogen	2.5	3.5
Phosphoric acid	0.6	0.4
Potash	8.0	4.0

It is seen that the stems contain more potash and phosphoric acid, and less nitrogen than the stalks.

In the manufacture of tobacco, nitrate of potash is sometimes used to improve the flavor of lower grades of tobacco and when such is practiced the value of the tobacco waste is increased. The potash and nitrogen in tobacco waste are in forms suitable for plant food. The potash is free from chlorides and mostly soluble in water. The nitrogen is as organic and nitrate; two-thirds of the former and one-third of the latter.

The wastes from tobacco factories are economical fertilizers to purchase provided the price is right. Often it may be possible for those living near tobacco factories to obtain such fertilizer cheap. This fertilizer also has a value as an insecticide. Tobacco wastes should be ground very fine before applying to the soil and in this form this material is ideal for fertilizing tobacco.

3. **Cotton-Seed Hull Ashes.**—A few years ago, before the value of cotton-seed hulls as a feed for live-stock was known, it was the custom to burn these hulls in the furnaces of the gins of the Cotton Belt, and dispose of the ashes for fertilizing purposes. In those days considerable cotton-seed hull ashes was to be found on our markets, but to-day it is rarely used. The practice of burning the hulls was indeed wasteful as the nitrogen was lost.

The composition of this product is variable as is evident from the results in the following table.

COMPOSITION OF COTTON-SEED HULL ASHES, 21 SAMPLES.[56]

	Average Per cent.	Maximum Per cent.	Minimum Per cent.
Moisture	7.97	—	—
Potash	23.93	32.80	15.20
Phosphoric acid	8.70	11.00	6.26
Lime	7.20	—	—
Magnesia	12.64	—	—
Insoluble matter	18.30	—	—

4. **Carbonate of Potash.**—This fertilizer is used to some extent by the tobacco growers of the Connecticut Valley. It was formerly obtained by lixivating wood ashes; the liquid was drawn off and concentrated, then evaporated to dryness and sometimes burned to drive off the organic matter. This process is still in vogue in parts of Canada and the United States. The impure product is known as pot-ashes, and pearl ash is the term applied to the purer product. It is also obtained as a by-product in the manufacture of sugar from the beet, which plant takes up considerable potash from the soil. The beet molasses, the remaining uncrystallizable product from the manufacture of sugar from the sugar-beet, is fermented with yeast and the sugar converted to alcohol and distilled. The residue is evaporated to dryness and the potassium carbonate is extracted.

Some of this substance is obtained from suint (the fatty substance of sheep's wool), which amounts to about 50 per cent. of the weight of the wool. The wool is washed with water which separates the suint. The solution is evaporated to dryness and the organic matter is burned off. The potassium carbonate is obtained by extracting this residue with water and allowing it to crystallize out.

The development of the Stassfurt mines has caused these methods to be almost entirely given up as potash can be manufactured from some of the Stassfurt salts on a large scale.

The carbonate of potash sold in this country usually carries 63 to 65 per cent. of potash and is very alkaline. It is a white

substance and soluble in water. It takes on moisture readily and for this reason it is usually put up in casks.

5. **Beet Molasses.**—The molasses obtained from the manufacture of sugar from the sugar-beet is quite rich in potash which gives this product its bitter taste thus making it unpalatable for human consumption. The ash of beet molasses contains from 10 to 15 per cent. of ash of which 7.5 to 12.25 per cent. is in the form of potash salts.

Composition of Beet Molasses Ash—Good Quality.[39]

	Per cent.
Potassium carbonate	45.30
Sodium carbonate	13.86
Potassium chloride	17.02
Potassium sulphate	8.00
Silica, lime, alumina, water, phosphoric acid, and undetermined	15.82

From the above it is seen that over 75 per cent. of the ash is as potash salts.

High grade potash manure carrying 6 to 9 per cent. of potash and beet refuse compound containing about 0.5 to 1 per cent. of potash are made from beet molasses. Beet molasses is generally used in the United States as a constituent of molasses feeds, as it brings a higher price for feed than for fertilizer. The fertilizer by-products are manufactured principally in foreign countries and imported into the United States. There is a new process for recovering the sugar in beet molasses wherein the molasses is destroyed for feeding purposes and the refuse from this process is sometimes used for making fertilizers.

Wine Residues.—Residues from the fermenting of wine contain potash.The pomace from grapes is sometimes burned and the potash obtained as carbonate.

Statistics.—The actual potash materials used in the manufacture of fertilizers for 1900 and 1905 were as follows:[32]

	1900 tons	1905 tons
Potassium nitrate	884	1,160
Kainit	54,700	190,493
Wood ashes	—	342
Other potash products	109,407	183,161

The total actual potash contained in the fertilizer manufactured was as follows: [32]

	1900 tons	1905 tons
Cotton-seed products	2 500	3,177
Potassium nitrate	371	487
Kainit	6,838	23,812
Wood ashes	—	22
Other potash salts	27,242	30,405
Total	36,591	57,843

Amounts of Potash Removed by Crops.—Voorhees estimates that the amount of potash removed annually from the soil by the principal crops in the United States is equivalent to 2,500,000 tons of muriate of potash or 1,250,000 tons of actual potash.[47]

The amounts of potash removed by some familiar crops are given in the table on page 200.

Amount of Potash in Soils.—Soils generally contain from 0.1 to 0.5 per cent. of potash, which is equivalent to 3,500 to 18,000 pounds of potash per acre to a depth of one foot.[18] Most of this potash is not available to plants and so a soil apparently rich in potash will often be helped by a supply in artificial forms. The addition of lime often increases the supply of available potash in soils, by promoting certain favorable chemical changes. The condition of the soil also influences the amount of available potash. Light sandy soils are more apt to be deficient in potash than heavy soils.

Forms of Potash.—A review of this chapter teaches us that potash exists chiefly in three forms in fertilizer materials.

As chloride in	Muriate of potash Sylvinit
As sulphate in	Sulphate of potash Double sulphate of potash and magnesia
As sulphate and chloride in	Kainit (action same as chloride)
As carbonate in	Potassium-magnesium carbonate Wood ashes Potassium carbonate

WEIGHTS OF AND POTASH REMOVED BY ORDINARY CROPS IN POUNDS PER ACRE.[37]

Name of crop	Wt. as harvested	Potash
Meadow day, 1½ tons	3.000	50.9
Timothy hay, 1½ tons	3,000	64.6
Clover hay, 2 tons	4,000	75.0
WHEAT		
Grain, 25 bus.	1,500	8.2
Straw	2,500	16.6
Total	4,000	24.8
RYE		
Grain, 30 bus.	1,680	10.0
Straw	2,000	18.7
Total	3,680	28.7
OATS		
Grain, 50 bus.	1,600	8.0
Straw	2,100	39.4
Total	3,700	47.4
BARLEY		
Grain 50 bus.	2,350	11.7
Straw	2,800	29.6
Total	5,150	41.3
CORN		
Kernel, 50 bus.	2,800	10.80
Cobs	700	0.42
Stover	2,300	3.82
Total	5,800	15.04
POTATOES		
Tubers, 200 bus.	14,000	67.2
Haulm (stems)	4,500	18.8
Total	18,500	86.0
SUGAR-BEETS .		
Roots, 20 tons	40,000	109.9
Tops	20,000	129.0
Total	60,000	238.9
MANGELS		
Roots, 25 tons	50,000	180.1
Tops	18,500	79.1
Total	68,500	259.2
TURNIPS		
Roots, 20 tons	40,000	138.2
Tops	11,600	42.4
Total	51,600	180.6
SWEDES		
Roots, 16 tons	32,000	69.0
Tops	4,800	16.7
Total	36,800	85.7
Cabbages, 20 tons	40,000	199.2
Onions, 500 bus.	28,500	63.5
Tobacco, leaf	1,500	67.3

The form of potash is an important consideration in the purchase of fertilizers, as potash in the form of chloride is injurious to the marketable value of certain crops as tobacco, potatoes, sugar-beets, and oranges. Muriate of potash seems to make potatoes waxy; with sugar-beets it seems to lessen the percentage of sugar as sucrose; for tobacco the flavor is spoiled for smoking; it sometimes forms calcium chloride in the soil which is not relished by plants.

The form of potash does not seem to work any injury on crops as legumes, grasses, corn, etc., and for such crops potash should be purchased in its cheapest form. Muriate of potash diffuses better in the soil than sulphate of potash. It should be understood that actual potash (K_2O) is not injurious to plants, but the form or elements it is associated with are the cause of its effect on crops.

Crop Producing Value of Potash Salts.—The Massachusetts Agricultural Experiment Station ran experiments with high grade sulphate of potash, low grade sulphate of potash, kainit, muriate of potash, nitrate of potash, carbonate of potash and silicate of potash, to determine the relative value of these salts for field crops. Each plot received potash (K_2O) at the rate of 165 pounds per acre. Nitrogen and phosphoric acid were supplied to all plots in equal amounts except for the nitrate of potash plots where allowance was made for the nitrogen in this salt. Some of the results of this experiment are found in the table on page 202.

Experiments to show the relative value of muriate and high grade sulphate of potash were conducted by the Massachusetts Experiment Station with some common crops. The potash salts were supplied in equal amounts, and nitrogen and phosphoric acid were also added.

"The sulphate of potash proves considerably superior to the muriate for the crops making most of their growth early in the season while for those making their growth in the latter part of the season the muriate is slightly superior."

COMPARISON OF DIFFERENT POTASH FERTILIZER MATERIALS FOR CROPS, IN YIELDS PER ACRE.

	Wheat		Corn, 4 varieties	Clover			Potatoes		Soy beans	
	Grain Bushels	Straw Pounds	Average Pounds	Hay Pounds	Rowen Pounds	Total Pounds	Large Bushels	Small Bushels	Beans Bushels	Straw Pounds
No potash	8.19	1,600	37,810	2,066	1,025	3,091	141.40	39.00	22.72	1,896
Kainit	10.43	1,475	40,610	2,544	1,471	4,015	207.03	31.03	16.96	1,350
High grade sulphate of potash	14.15	1,877	37,530	2,357	1,056	3,413	217.66	31.73	25.86	1,984
Low grade sulphate of potash	14.15	2,595	39,375	2,485	1,218	3,703	221.09	30.56	22.76	1,712
Muriate of potash	15.64	1,877	40,490	2,416	1,271	3,687	223.70	38.33	23.03	1,728
Nitrate of potash	16.38	3,083	40,435	2,232	1,170	3,402	215.33	36.23	23.38	2,036
Carbonate of potash	14.89	2,458	40,155	2,223	1,112	3,335	209.86	53.10	27.86	2,288
Silicate of potash	17.13	2,055	39,240	2,399	1,226	3,625	199.86	42.13	25.40	2,024

	Yield per acre	
	Muriate of potash	Sulphate of potash
Rhubarb, lbs.		
Stalks	8,421	8,559
Leaves	11,957	14,286
Cabbage, lbs.		
Hard heads	872	2,071
Soft heads	22,791	24,319
Pototoes, bus.		
Market	208	215
Small	53	39
Onions, bus.	110	75
Scallions, lbs.	10,811	8,828
Timothy and clover hay, lbs.	4,710	4,725
Timothy and clover rowen, lbs.	1,745	1,997

Fixation of Potash.—Potash is quickly fixed in the soil; it replaces the sodium and calcium in soils and forms compounds insoluble in water. The chlorides of potash are liable to render the lime content of a soil deficient, as the chlorine unites with lime and forms a soluble compound that is readily leached from the soil. In experiments at the Massachusetts Experiment Station, Goessmann found that continued applications of muriate of potash produced sickly crops which were made well and healthful by an application of lime. Therefore acid soils should always receive an application of lime before the use of potash as chloride. As potash is quickly fixed in the soil and the chlorides washed out, it is often advisable to apply chloride of potash some time before the crop is planted, especially when the crop that is to be planted is injured by chlorine. The fixation of potash usually occurs in the surface soil and so rapidly does this fixation take place on some alluvial soils, that it is necessary tc work it in soon after applying to insure an even distribution.

Functions of Potash.—The intelligent use of potash fertilizers requires a knowledge of the effect of this constituent on crops. Potash is essential to the formation of starch, sugar and cellulose (pure fiber) in plants. When there is a deficiency of available potash in soils, certain plants do not mature well.

Potash Favors the Formation of Carbohydrates.—The effect of potash on the sugar content of mangolds in shown in the following table.[9]

Fertilizer	Leaf per acre tons	Roots per acre tons	Sugar per acre tons
Nitrogen and phosphoric acid	2.95	12.00	0.797
Nitrogen, phosphoric acid and potash	3.25	28.95	2.223

The two plots received equal quantities of ammonium salts and superphosphate. The plot that received potash shows a yield in roots of about 2½ times more than the plot that had no potash. The leaf development per acre was nearly the same in both plots and as the roots of this crop are made up largely of carbohydrates the effect of potash is readily seen.

Another system of fertilizing mangolds gave the following results.[9]

AVERAGE OF 12 YEARS.

Fertilizer	No potash Tons	+ Phosphates and potash Tons
Manure only	18.6	19.5
Manure and nitrate of soda....................	27.7	26.8
Manure and ammonium salts....................	21.8	25.9
Manure and rape cake	24 9	28.6
Manure, rape cake, and ammonium salts........	24.2	29.9

The above data show that potash increased the yield in every case except where nitrate of soda was added. The soda present in nitrate of soda renders unavailable potash in the soil available, which accounts for this increase. It is also seen that the addition of potash to manure was beneficial. This is interesting because 14 tons of manure was applied per acre which amount supplied considerable potash, yet was unable to furnish all the potash needed for this crop.

Potash Benefits Legumes.—Another beneficial effect of potash is the increase it gives to the growth of legumes. At Rothamstead the yields of plots of mixed grasses and legumes show this effect.[9]

Fertilizer	Dry hay		Composition of Herbage in 1902		
	1856 to 1902 Cwts.	1893 to 1902 Cwts.	Grasses Per cent.	Leguminous plants Per cent.	Weeds Per cent.
Complete mineral fertilizer	38.8	36.5	20.3	55.3	24.4
Nitrogen and phosphoric acid	28.1	21.6	28.8	22.1	49.1
Superphosphate only	23.3	17.8	54.4	15.4	30.2
Unfertilized	21.9	15.9	34.3	7.5	58.2

The complete mineral manure consisted of phosphates and sulphates of potash, soda and magnesia. The plot receiving the complete mineral manure gave the highest yields and also showed the greatest percentages of legumes and least of weeds. The plot receiving nitrogen and phosphoric acid without potash gave the next highest yields and shows a larger percentage of leguminous plants than the plots that received phosphates and no fertilizers. On the unfertilized plot the percentage of leguminous plants is very low. The effect of the soda in the mineral fertilizer without potash, which comes second in the above table, is shown by the comparatively higher yields over the plot that received phosphates only. It is thus evident that potash is the most important fertilizing constituent for legumes and large applications of phosphoric acid do not increase their growth materially.

Potash Favors Seed and Straw Formation.—Hall says: "On these grass plots another very striking effect of potash manuring is also very manifest. On the potash-starved plots the grasses fail to a large extent to develop any seed, and the heads are soft and barren, presumably because of the deficiency in carbohydrate formation. For the same cause the straw, not only of the grasses, but also on the similarly manured wheat and barley plots, is also weak and brittle when potash is wanting.[9]

Potash Effects the Leaves.—Grass grown on soils deficient in potash tends to show the effect of this constituent by producing a brown sickly appearance. The grass blades often turn brown about 2 inches from the tip and die off. The leaves of root

crops also often show a lack of potash when they are nearing maturity, by a spotted brown coloration.

Potash Effects Maturity.—Experiments show that soils without sufficient potash do not produce as valuable grain crops in dry seasons as soils rich in this constituent. This is probably due to the fact that potash causes a longer growing period and holds back maturity. With root crops the opposite effect has been found to exist. That is the maturity of these crops is hastened by a supply of potash.

Potash Helps to Neutralize Plant Acids.—Many plants contain acids; for example, in the grape there is tartaric acid; in the apple, malic; in the orange, citric; and potash helps to neutralize these plant acids and form acid salts.

Potash Sometimes Checks Insect Pests and Plant Diseases.—Experiments show that certain forms of potash are distasteful to some insects and tend to check their ravages. Potash seems to make plants better able to resist attacks of certain fungi, especially when soils are deficient in this constituent, by producing a stronger and more vigorous growth.

CHAPTER X.

MISCELLANEOUS FERTILIZER MATERIALS.

The fertilizer materials discussed in the previous chapters are those products most commonly used and constitute the main sources of nitrogen, phosphoric acid and potash. There are, however, other substances that are occasionally utilized that have some value. Some of these materials are used at times by fertilizer manufacturers while others are employed directly by farmers. Some of them furnish one or more of the essential elements in amounts sufficient to warrant their use, when they can be obtained cheaply, while others are not applied for their fertilizer value but to improve the condition or texture of the soil, to increase the available plant food supply or to conserve moisture. There are some products discussed in this chapter that have no particular value as fertilizer but are taken up to set clear impressions that are prevalent among some who feel that these products can be used to replace to a certain extent the more important fertilizer materials. It should be remembered that many of these materials we are about to discuss do not contain sufficient amounts of the essential elements to produce paying crops but they may be used to partially replace commercial fertilizers.

Compost.—A compost is usually made up of layers of manure and vegetable matter. Sometimes lime, acid phosphate, ground raw rock phosphate, cotton-seed, gypsum, and similar fertilizer materials are added to it. A compost can be made in the following manner. First select a shady place and provide a good drainage. Then make a foundation with a layer of earth. On top of this place a layer of leaves or manure then a layer of earth, another layer of leaves, cotton-seed and manure, a layer of earth, etc. The top of the compost should be covered with earth and it should be shaped to shed water. The compost should be kept moist to prevent the loss of nitrogen as ammonia. The manure, leaves, cotton-seed, raw rock phosphate, etc., will decay or undergo changes due to the action of organisms similar

to what would take place in the soil, when the compost is kept thoroughly moist. Before applying any of the compost to the land it should be well mixed to make it uniform. The earth is used in layers to absorb the ammonia that may be set free in the process of decay of the organic materials. The amount of fertilizing material obtained from a compost will be equal to the amount of fertilizer material added to it, provided there is no loss; but the availability of these materials will be greater.

Seaweed.—In states bordering on the ocean seaweed is used a great deal for fertilizer. Stormy weather throws considerable quantities on the beach and the states of Rhode Island, New Jersey, New Hampshire, and Massachusetts have used this fertilizer for many years. Storer says: "Here in New England there is abundant evidence of the great value of seaweed. Abundant crops of hay and (in former times more than now) of potatoes are there grown and sold year after year, while the country remains fertile and fortunate. It is interesting to see the fields in that region remain green throughout the summer droughts, at times when the scantily manured fields of the interior are brown and parched. It is not the showers of summer alone, but the good tilth which comes with cultivation and careful tillage, as well as abundant supplies of plant food, which enable crops to support intense heat. In the district now in question, (behind Rye Beach in New Hampshire) the use of the seaweed extends back some eight or ten miles from the beach, and to a less extent, even to twelve and fourteen miles.[57]

The best way to apply seaweed is in the fresh state. The different varieties of seaweed contain from 70 to over 80 per cent of moisture and when it is to be transported any considerable distance it may be spread thin and sun-dried to avoid carting so much water. Should it rain during the process of sun-drying some of the nitrogen and potash might be washed away. In some of the European countries the seaweed is thrown in heaps to dry and rot. Such practice, because fermentations set in, necessarily causes losses of nitrogen as ammonia, and of potash by leaching. In some countries seaweed is composted

and the same precautions should be exercised as in composting farm manure or else losses will occur. Preservatives as gypsum may prevent the loss of considerable nitrogen. The experience of the New England farmers shows that better results are secured when the seaweed is not composted. In New England fresh seaweed is used as a top dressing for grass or plowed in.

About 20 to 25 per cent. of the ash of seaweeds is chlorine. Therefore it would be safer to use some other fertilizer for tobacco, potatoes, etc. Seaweed is rather quick acting and gives up its fertilizer constituents during the first season.

ANALYSES OF DIFFERENT VARIETIES OF SEAWEED.[58]

	Round-stalked rock-weed—Ascophyllum (Fucus) nodosum	Flat-stalked rock-weed—Fucus vesiculosus	Phyllophora membranifolia	Cladostephus verticillatus	Ahnfeldtia plicata	Dulse or dillesk—Rhodymenia palmata
Water	77.26	76.55	66.18	71.17	59.04	86.25
Nitrogen	0.24	0.38	1.08	0.45	1.35	0.37
Phosphoric acid	0.08	0.12	0.14	0.22	0.25	0.09
Potash	0.64	0.65	0.96	1.42	0.59	1.07
Lime	0.48	0.45	5.11	0.87	0.98	0.46
Magnesia	0.35	0.31	0.69	0.36	0.29	0.09
Insoluble matter	0.03	0.04	1.59	1.43	0.44	0.09

From the above table it is seen that seaweed is as valuable as farm manure from a fertilizer standpoint although the benefit derived from farm manure is more lasting. The percentages

ANALYSES OF THE ASH OF SEAWEED.[38]—Forchammer.

	Fucus digitatus per cent.	Fucus vesiculosus per cent.	Fucus serratus per cent.
Potash	20.66	13.01	3.98
Soda	7.65	9.54	18.67
Magnesia	6.86	6.12	10.29
Lime	10.98	8.36	14.41
Phosphoric acid	2.36	1.16	3.89
Sulphuric acid	12.33	24.06	18.59
Ferric oxide	0.57	0.28	0.30
Silica	1.44	1.15	0.38
Sodium chloride	26.18	21.45	16.50

of nitrogen and potash are quite considerable and show this to be a valuable fertilizer for farmers living near the coast.

When seaweed is burned the nitrogen and organic matter are lost so that it is more economical to apply seaweed fresh than when burned to ash.

Marl.—There are two principal classes of marls, namely shell marls and green sand marls. The shell marls contain less phosphoric acid and potash and more lime than the other marls.

ANALYSES OF MARLS.

	Shell marl	Green sand marl
Phosphoric acid	0.31%	2.20%
Potash	0.59	4.70
Lime	—	2.90

The Maryland Experiment Station gives the following as an average composition of 24 marls.[17]

	Average	Range
Phosphoric acid	0.38%	1.0 to 2%
Potash	1.39	2.5 to 3

The Kentucky Experiment Station gave the following as an average of 22 marls (character not specified):[17]

	Per cent.
Phosphoric acid	0.047
Potash	2.200
Lime	1.110

The plant food in marls is not quickly available.

Voorhees says: "Marl, however, is an important amendment to soils, not only because of its content of mineral constituents, but because these constituents are associated with products that exert a very favorable mechanical effect upon soils. Large areas of land in the state of New Jersey, formerly unproductive, chiefly because of physical imperfections, have been made very productive mainly through the application of marl.

"The use of marl is now less general than when the fertilizing constituents from artificial sources were dearer, and when

the labor of the farm was more abundant and cheaper. The quicker effect of more soluble fertilizer constituents has had an influence in reducing the use of marl where quick returns are desirable. Where farmers have deposits of marl upon their own farms, or within short distances of them, and can secure it at a low price per ton, its application is a desirable method of improving land.

"The results from the use of marl are frequently due quite as much to the improvement given to the physical condition of soils as to the increase in fertility furnished by the essential mineral constituents. Marl may be carted and spread upon the land when other work of the farm is not pressing, thus making it possible to get a considerable addition of fertility at a small expense."[59]

Peat and Muck.—In low wet places where vegetable matter accumulates, decomposition sets in and the substance formed is called peat or muck. This material does not run high in the essential elements; it averages about 0.7 per cent. of nitrogen and about 75 per cent. of water. The phosphoric acid and potash contents approximate what is contained in good soil. The value of this substance depends upon its nitrogen content which in turns depends upon the amount of organic matter. The nitrogen is not perhaps as available as that in cultivated soils and unless it is easy to obtain it is doubtful whether it pays to use it.

If the land could be drained its greatest value would be obtained by growing crops on it. It is generally put in heaps and allowed to sun-dry before using. As an absorbent, peat is used in stables and it is also used in fertilizers as a dryer.

Average of Six Analyses of Muck and Peat From Various Stations.[17]

	Per cent.
Water	69.20
Nitrogen	0.32
Phosphoric acid	0.11
Potash	0.08

Average of Ten Analyses of Partially Dry Muck From Various Stations.[17]

	Per cent.
Water	27.78
Nitrogen	1 02
Phosphoric acid	0.23

Average of Seven Analyses of Muck From Various Stations.[17]

	Per cent.
Water	34.87
Nitrogen	1.00
Phosphoric acid	0.25
Potash	0.39

Liquid Fertilizers.—In the Eastern States liquid fertilizers are sometimes sold for use on house plants. These fertilizers contain the nitrogen, phosphoric acid and potash in solution. They are put up usually in pint or quart bottles and the liquid is often colored. The price of these fertilizers is generally rather high considering the fertility present. These fertilizers are sold under attractive names.

Analyses of Liquid Fertilizers.[60]

	Per cent.	Per cent.
Water	90.89	82.36
Nitrogen	0.70	3.22
Soluble phosphoric acid	0.16	3.59
Potash	2.89	3.30
Selling price per ton	—	$1,000.00

Flower Fertilizers.—Some of the seed dealers put out fertilizers in packages of 15 pounds to a few ounces in weight to be used for flowers or house plants. These fertilizers usually sell for exorbitant prices, sometimes as high as $1,000 per ton, but they cannot be compared to regular commercial fertilizers as they are purchased in such small amounts. Fertilizers are also put out in tablet and cartridge forms for use on house plants. The tablet or cartridge is supposed to be sufficient for one house plant of ordinary size.

ANALYSES OF FLOWER FERTILIZERS.[60]

	Per cent.						
Nitrogen	4.39	16.18	3.29	3.38	6.56	13.33	4.91
Total phosphoric acid	10.66	4.00	6.62	10.44	3.38	23.54	12.56
Available phosphoric acid	9.40	4.00	4.54	9.54	2.92	23.54	7.40
Potash	4.84	4.82	5.80	3.64	6.60	26.57	4.80
Ton price	$80.00	$1,000.00	$50.00	X	$298.00	$140.00	$249.90

X = 15 to 25 cents a package.

Pulverized Manures.—Pulverized sheep manure, poultry manure, and pigeon manure are found on the market in some sections. These manures usually carry a higher price than the regular commercial fertilizers although they are not so valuable. These products should be saved on the farm but it will hardly pay to purchase them unless the price is much less than for commercial fertilizers. The value of these manures is often exaggerated because they are quick acting. They are to be found for sale in seed stores and are purchased generally in small amounts by those having small gardens or house plants.

ANALYSIS OF PULVERIZED SHEEP MANURE, COMMERCIAL PRODUCTS.[61]

	Per cent.				
Nitrogen	2.31	2.17	2.52	2.58	2.50
Phosphoric acid	1.53	1.44	1.47	1.52	1.54
Potash	3.21	1.02	2.17	2.00	1.41
Moisture	9.80	7.53	—	—	—
Ton price	$40.00	$35.00	—	—	—

Fresh Fish Scrap.—Farmers living near the sea coast use a great deal of fresh fish scrap and whole fish. This material contains nitrogen and phosphoric acid but an average composition is impossible to give because the moisture content is so variable. Fish scrap may have the following limits of composition:

VARIABILITY OF FISH SCRAP.

	Per cent.
Water	25.0 to 75.0
Nitrogen	7.5 to 2.0
Phosphoric acid	6.0 to 1.5

Dry ground fish is in a better mechanical condition than fresh fish scrap so that the latter material is not quickly decomposed in the soil and therefore not so available as plant food.

Fresh fish are also often composted. The main value in fish is derived from the nitrogen they contain. The farmer in purchasing fresh fish products should pay according to the amount of moisture present. More nitrogen and phosphoric acid are obtained when the product is dry than wet, hence the dry material is more valuable.

Lobster shells may be utilized as fertilizer. The following analysis shows its value.

	Per cent.
Water	7.27
Nitrogen	4.60
Phosphoric acid	3.52
Lime	22.24
Magnesia	1.30
Insoluble matter	0.27

Fresh lobster shells would no doubt contain more water than the above although the nitrogen, phosphoric acid and lime are high enough to make this material worth while because it can usually be purchased very cheap.

Mussels.—Along the coasts of some states there are large quantities of mussels which may be obtained for nothing or at a very low price. The New Jersey Experiment Station gives the following analysis of mussels.[62]

	Per cent.
Water	68.19
Nitrogen	0.90
Phosphoric acid	0.12
Potash	0.13
Lime	15.84
Organic matter	7.92
Mineral matter	23.89

This bulletin states that hundreds of tons of mussels can be had at a cost less than $2 per ton delivered on the farm and that it is customary to compost this material with land plaster (gypsum) and sand. Mussels decay quickly in the soil and furnish organic matter which helps to build up soils.

Shrimp waste is sometimes available along the coast of some of the Gulf States.

ANALYSES OF SHRIMP WASTE.

	Per cent.	Per cent.	Per cent.
Phosphoric acid	9.95	9.15	3.40
Nitrogen	2.87	3.03	7.09
Potash	—	0.68	—
Water	8.09	10.33	—

This is a good fertilizer and runs higher in the essential elements than when it carries more water, which is usually the case. It is quite rich in phosphoric acid, and the nitrogen content although not as high as in fish scrap is nevertheless high enough to consider. Farmers living where shrimp waste is available may often supply part of their fertilizer from this source.

King crab is not always dried and ground but is often employed in the fresh state. It is richer in nitrogen (containing 2 to 2.5 per cent. of this element) than many wet fish wastes, and because of its rapid decomposition in the soil it is sometimes an economical fertilizer for those living near the supply. It is sometimes put in a compost and used in this way.

Sewage.—The average composition of human excreta and the amount produced per year by the average individual is as follows:[1]

COMPOSITION OF HUMAN EXCRETA.[63]

	Faeces		Urine	
	Per cent.	Pounds per year	Per cent.	Pounds per year
Water	77.2	—	96.3	—
Organic matter	19.8	—	2.4	—
Ash	3.0	—	1.3	—
Nitrogen	1.0	1.04	0.6	6.9
Phosphoric acid	1.1	1.30	0.17	3.2
Potash	0.25	0.30	0.2	3.4

These figures are taken as an average for all ages. For adults the amounts per year would be greater. Although the amounts of fertilizer constituents is low for the individual the quantity

of nitrogen, phosphoric acid and potash amounts to a great deal with a large population. It is customary in many of our cities and towns to pipe this human excreta, as sewage, to the sea or to rivers. So in the aggregate the loss of fertility from human excreta is enormous. There have been many methods tried to prevent this loss and save this material for fertilizer, but these experiments have been found impracticable because they are either unsanitary or else cost more than the same amount of fertility does from other substances. It is of course possible to save human excreta but it doesn't pay on account of the danger to public health. Where earth closets are used the remains may be composted and the paper etc., will decay through the action of bacteria.

In most places the excreta is carried away with an excess of water as sewage. In some sections this sewage is poured on the land, which is regulated by ditches. Another method consists of conducting the sewage through underground pipes, by pressure. These pipes have couplings at convenient places and the sewage is distributed with a hose. Another method somewhat similar to the last one is sometimes employed and consists of distributing the sewage through porous pipes.

The continual distribution of sewage over land is injurious. The soil becomes clogged or filled up with the slimy matter in suspension. Where the irrigation of sewage is practiced the soil should be allowed a rest so as to be kept thoroughly aerated to allow the soil organisms a chance to carry on their necessary functions.

It is estimated that the sewage from cities using the sanitary closet contains about 2.2 parts of nitrogen per 100,000 parts of sewage.

Composition of Sewage.[56]

Water	Nitrogen	Potash	Phosphoric acid
78.07%	0.40%	0.27%	0.85%

Sewage Sludge.—By the use of certain chemicals (lime, sulphate of iron, alum, perchloride of iron, etc.) the suspended matter in sewage is precipitated and separated from the resulting clear liquid portion with the organic matter. This remain-

ing portion is then put in a filter press and the excess of water is squeezed out. The resulting product is called sewage sludge, which has some value as fertilizer.

COMPOSITION OF SEWAGE SLUDGE.[9, 56]

	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Water	10.1	31.2	40.6	3.55	37.74
Organic matter	49.8	24.8	16.8	38.22	—
Nitrogen	2.32	0.94	0.55	1.65	0.91
Phosphoric acid	2.27	0.80	1.42	1.25	0.61
Lime	2.34	24.6	24.45	8.40	3.10
Potash	traces	traces	traces	traces	0.25
Insoluble matter	23.27	7.06	5.57	28.28	28.70
Magnesia	—	—	—	—	2.19
Iron and aluminum oxides	—	—	—	—	8.55
Carbonic acid	—	—	—	—	4.89

The above analyses show that sewage sludge is not a very valuable fertilizer; that is, the farmer could not well afford to purchase this material on the market. Sewage and sewage sludge would benefit sandy soils more than heavy soils because they contain organic matter. In addition the sludges rich in lime may sometimes prove beneficial.

Coal ashes sometimes helps to improve the condition of certain soils. This material does not contain enough of the essential elements to be valuable as fertilizer but its indirect action may help to produce better physical properties in soils. This material is perhaps more valuable for walks and roads than for fertilizer.

Lime-kiln Ashes.—When lime and wood are burned together in making quick-lime the resulting product is known as lime-kiln ashes.

COMPOSITION OF LIME-KILN ASHES.

	Range Per cent.	Average Per cent.
Potash	0.50 to 4.50	2.00
Phosphoric acid	0.25 to 1.50	0.75
Lime	38 to 45	40.00

This product is richer in lime than wood ashes and it may be used on soils requiring lime when the price is reasonable.

ANALYSES OF LIME-KILN ASHES.[55]

	10 Mass. analyses Per cent.	Conn. analyses Per cent.	Conn. analyses Per cent.
Moisture	11.35	—	—
Potash	2.04	1.11	2.77
Phosphoric acid	0.78	0.89	1.07
Lime	41.49	35.32	38.33
Magnesia	1.30	8.00	10.80
Insoluble matter	6.78	—	—

Tan bark ashes show the following composition.

	Range Per cent.	Average Per cent.
Potash	0.6 to 2.9	1.9
Phosphoric acid	0.15 to 2.8	1.4
Lime	—	31.0

Tan bark ashes are not a valuable fertilizer but may be used economically by farmers when they are cheap. They contain about the same amount of lime as wood ashes but are much lower in potash.

Rice Hull Ashes.—In the rice sections the rice hulls are often used as fuel in the boilers of rice mills. This product has about the following composition:

	Per cent.
Potash	1.2
Phosphoric acid	0.6
Silicious matter	80.0

It usually doesn't pay to use this by-product because in the regions where it may be had the soils are rich in potash. This material is rich in silicious matter (sand).

Corn Cob Ashes.—In certain sections of the country corn cobs are sometimes used in place of wood for fuel.

ANALYSIS OF CORN COB ASHES.[56]

	Per cent.
Moisture	1.20
Potash	7.08
Phosphoric acid	2.37
Lime	11.70
Magnesia	1.28
Insoluble matter	52.09

From this analysis it is evident that these ashes are valuable for soils in need of potash. It also contains an appreciable amount of phosphoric acid. Farmers burning corn cobs will do well if they save these ashes and apply them to their land.

Leather Scrap Ashes.—Sometimes leather scrap is burned and the ashes used for fertilizer.

COMPOSITION OF LEATHER SCRAP ASHES.

	Per cent.
Potash	3.00
Phosphoric acid	3.5-4
Lime	2.5

Farmers living near factories where these ashes accumulate should utilize this material if they can obtain it for the hauling.

Brick kiln ashes are sometimes used for fertilizer.

ANALYSES OF BRICK KILN ASHES.[55]

	Per cent.
Water soluble potash	2.10
Lime	41.98
Magnesia	3.65
Phosphoric acid	1.89
Sand and clay	19.91
Charcoal	0.67

The kind of wood burned in brick kilns will influence the value of these ashes. They are worth purchasing by those living near brick kilns who wish to apply lime, when they can be purchased right.

Ivory Dust.—This is a valuable fertilizer but like bone it is slow acting unless acidulated.

COMPOSITION OF IVORY DUST.[56]

	Per cent.
Nitrogen	6.64
Phosphoric acid	24.56
Ash	52.63

Spent Hops.—This material is high in water and furnishes a little more than one-half the organic matter that is found in manure.

ANALYSIS OF SPENT HOPS.[55]

	Per cent.
Water	83.63
Organic and volatile matter	15.48
Mineral matter	0.89
Total	100.00
Nitrogen in organic matter	0.77
Phosphoric acid in mineral matter	0.18
Potash in mineral matter	0.88

Soot is the black deposit that collects in flues and chimneys when coal or wood is burned and is used in England quite extensively as fertilizer. Soot from coal averages about 3 per cent. of nitrogen in the form of ammonia. It is more valuable in improving the physical condition of soils than as a fertilizer. Its dark color increases soil temperature by absorbing the rays of the sun, thus helping plant growth and the action of the soil organisms. It lightens heavy soils and is not relished by certain insects that damage crops.

ANALYSES OF SOOT.

	Soft coal[18] Per cent.	Hard wood[64] Per cent.	Wood Per cent.	Hard coal Per cent.
Potash	0.84	1.78	2.40	0.01
Phosphoric acid	0.75	0.96	0 40	0.40
Nitrogen	—	—	1.30	2.40

ANALYSES OF SOOT BY THE CONNECTICUT EXPERIMENT STATION.

Nitrogen as ammonia	3.40	—
Nitrogen, organic	1.12	—
Total nitrogen	4.52	6.32
Water soluble potash	0.71	0.80
Moisture	—	9.63
Organic matter	—	45.56
Mineral matter	—	44.81

Street sweepings are sometimes used by gardeners. When they contain a large proportion of horse manure they may have a little value. However, the liquid portions are not saved so that they are not as valuable as farm manure. Street sweepings usually contain other debris than horse manure which of course decreases their value. Generally speaking, street sweepings should not be used unless the expense of hauling is very small. Most people would not care to utilize this waste because of the unsanitary nature of it. Debris from houses, etc., are liable to contaminate it in which case it would not be a safe fertilizer.

Potassium nitrate, or saltpeter, has been known for a long time and is found as an efflorescence in soils in the neighborhood of towns, especially in hot climates, where urine and organic matter rich in nitrogen are present. It is formed by the action of nitrifying bacteria. Up to the time of the Crimean War (1852-5) the natural supply proved ample but during that war this salt was for the first time made from sodium nitrate (Chile saltpeter).

COMPOSITION OF POTASSIUM NITRATE.

	Pure Per cent.	Commercial Per cent.
Nitrogen	13.60	12 to 13
Potash	46.59	40 to 45

This is a good fertilizer but the market price prohibits its general use. Sodium nitrate and potash salts (Stassfurt) are cheaper sources of nitrogen and potash than potassium nitrate. It is used to a limited extent in the manufacture of commercial fertilizers.

Ammonium nitrate is a rich nitrogenous salt but it is too expensive to employ for fertilizing purposes.

Silicate of Potash.—Some minerals as feldspathic rock contain considerable amounts (12 to 15 per cent. and more) of potash. These potash feldspars have been ground to a powder and put upon the market for fertilizer from time to time. The United States Department of Agriculture[65] has called attention to the possible value of these minerals as a source of potash for fer-

tilizer. The following table may prove of interest here in showing the relative value of feldspar and potassium sulphate on the growth of wheat and Japanese millet.

VEGETATION EXPERIMENTS WITH WHEAT AND JAPANESE MILLET.

	Wheat				Japanese millet	
	Wt. of air dry crop-grams			Average relative weight of total crop		
	Straw and chaff	Grain	Total crop		Weight of air dry crop-grams	Average relative weight total crop
No potassium	30.5 28.4	13.2 13.6	43.7 42.0	100	16.8 15.3	100
2.75 grams ground feldspar	30.8 31.1	14.0 14.8	44.8 45.9	106	17.8 15.6	104
6.88 grams ground feldspar	32.2 31.8	14.3 14.3	46.5 46.1	108	19.3 18.5	118
11 grams ground feldspar	30.5 31.4	14.1 14.4	44.6 45.8	105	18.6 18.1	114
0.5 grams sulphate of potash	37.6 37.8	17.8 18.6	55.4 56.4	130	35.0 33.2	212
1.25 grams sulphate of potash	41.8 42.6	19.6 18.7	61.4 61.3	143	32.3 33.8	206
2 grams sulphate of potash	42.6 44.0	19.5 20.5	62.1 64.5	148	42.0 37.5	248

The maximum increase in relative weights for feldspar are 8 on wheat and 18 on millet, while sulphate of potash shows 48 for these crops, a decided difference indeed. The Rhode Island Experiment Station says of these experiments: The finely ground feldspathic rock, which was used in the experiments recorded in this connection, was of such slight value as a source of readily available potassium as to be practically useless, if the pot experiments are to be considered as a criterion.

"The root systems of wheat and Japanese millet are sufficiently well developed so that these plants should have been much

more able to have obtained the potassium of feldspar than many of the quick-growing market-garden crops.

"The farmer can not afford to experiment with finely-ground feldspathic rock until there are better prospects of success than are discernible at present."[66]

The Massachusetts Experiment Station has conducted experiments using different potash salts on several crops showing that silicate of potash is quite inert.

Potash feldspars have been heated with salts of soda or lime in order to render the potash more soluble[9] but the cost of such procedure has prevented introducing it on account of the cheapness of the Stassfurt salts.

Cushman concludes as a result of abstracts from experiments and from tests that: "At the present stage of the investigation it would be extremely unwise for anyone to attempt to use ground feldsphatic rock except on an experimental scale that would not entail great financial loss."[67] He also warns against exaggerated and sensational claims that may be made concerning this material as a source of potash.

PRODUCTION AND VALUE OF FELDSPAR, 1901-1905.[39]

Year	Short tons					
	Crude		Ground		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1901	9,960	$21,669	24,781	$198,753	34,741	$220,422
1902	21,870	55,501	23,417	194,923	45,287	250,424
1903	13,432	51,036	28,459	205,697	41,891	256,733
1904	19,413	66,714	25,775	199,612	45,188	266,326
1905	14,517	57,976	20,902	168,181	35,419	226,157

Iron sulphate is produced quite extensively as a by-product in the manufacture of steel. Although iron is necessary for plant growth most plants do not use more than 15 pounds of iron oxide per acre and average soils contain 15 tons of this material per acre in the surface soil to a depth of 9 inches. So it is evident that soils contain abundant amounts of iron for the needs of

plants. Iron produces a green color in plants and is necessary for chlorophyll formation. The bright color in fruits and flowers has often been attributed to applications of iron salts but experiments along this line have not shown this to be true. It is said that a soil may contain plenty of insoluble iron but not enough soluble iron for the formation of chlorophyll. Enough iron is soluble in the weak soil acids to supply the needs of plants so that this material need not be considered when applying fertilizers.

Common salt, or sodium chloride, has been used for many years in some of the older countries as a fertilizer. In this country a product called agricultural salt has been on the market, which is mainly common salt. Most of our soils are rich enough in sodium so that applications of common salt are not necessary. This material does not furnish any nitrogen, phosphoric acid or potash as the following analyses show:

ANALYSES OF COMMON SALT.

	England[38]		Russia[38]		Louisiana	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Chloride of sodium	96.86	96.70	91.49	74.84	99.10	96.53
Chloride of calcium	0.49	0.68	1.10	5.21	—	—
Sulphate of lime	0.74	0.25	—	—	0.56	3.21
Chloride of magnesium	—	trace	2.05	3.57	—	—
Chloride of aluminium	—	—	2.60	1.17	—	—
Sulphate of sodium	—	—	2.76	15.21	—	—
Water	0.33	0.63	—	—	0.10	0.20
Insoluble matters	1.58	1.74	—	—	—	—

Warington states: "Salt supplies no essential ingredients of plant food. The little value which salt possesses as a fertilizer is probably due to its action in the soil, where it may help to set free more important constituents."

The Rhode Island Experiment Station says: "The beneficial action of common salt may be attributed to four reasons, viz.: 1. Sodium is a natural constituent of all our agricultural plants; and some soils, so far inland that they get little of it in the rain water, or in which it is naturally deficient, may contain such

small quantities that its application supplies the plant with a direct manure which is lacking. It should be borne in mind, however, that all of our commercial fertilizers contain considerable quantities of potash, usually in the form of muriate of potash or kainit, and that every hundred pounds of the former contains about 15 pounds of common salt and of the latter about 35 pounds. In consequence of this fact the farm upon which considerable quantities of commercial fertilizer are used is little liable to lack soda. 2. Salt is considered by some as serviceable in destroying fungi and freeing land from grubs. 3. It acts as a solvent upon other elements in the soil, thus enabling the plant to obtain them, serving thus as an indirect manure. To this effect may be attributed, mainly, the beneficial action of salt, though muriate of potash, would, doubtless, in most cases, have the same effect and at the same time supply a more necessary element. 4. It attracts moisture and might therefore be beneficial in a dry season."[58]

When salt is applied in large amounts it injures vegetation. In small quantities it acts on the phosphates of lime compounds and renders the phosphates soluble. It also tends to decompose organic matter. Its market value is usually about $4 to $6 a ton and at this price the farmer cannot afford to use it since it may be had for nothing when bought in kainit, muriate of potash, and sylvinit, etc.

Powder waste is another product that is principally made up of common salt. Some of this material may contain nitrates in which case it is more valuable than common salt, although it should not be considered unless it can be had for nothing, or very cheap. It should be applied in small quantities because of the deleterious action that large applications of sodium chloride have on vegetation.

Sulphates of Magnesia and Soda.—According to M. Dejardin: "Magnesia forms a very important constituent in all soils in which the French vine (grape) resists the attacks of Phylloxera vastatrix. We find, also, that the American vine flourishes best in these soils containing a high percentage of magnesia. The

amount of magnesia in the ash of the Styrian vine, according to an old analysis, is 6.55 per cent. Therefore, from soils deficient in this ingredient, it is impossible to obtain full or healthy crops. Probably the ravages of the Phylloxera may be traced to the growth of sickly plants season after season, the unhealthy nature being due to the want of small quantities of such mineral ingredients in the soils cultivated as iron and magnesia."[38]

MAGNESIA IN THE ASHES OF PLANTS.[38]

Wheat, grain		Sugar-cane		Oats, grain		Clover		Rice	Potato
13.54	9.6	11.78	6.84	8.7	7.7	8.28	6.9	11.96	9.4

Sulphate of soda, (salt cake), is sometimes obtained as a by-product in the manufacture of nitric acid from nitrate of soda. When it contains nitrate of soda it has some fertilizing value. Experiments at Rothamstead show the following yields from some alkaline salts.

EFFECT OF ALKALINE SALTS UPON WHEAT.[9]

Alkaline salt added to ammonium salts and superphosphate in manure.	1852-1861	1862-1871	1872-1881	1882-1891	1892-1901
	Grain, bushels				
None	28.4	27.9	21.7	22.7	19.5
Sulphate of soda	33.4	34.3	25.1	30.1	26.7
Sulphate of potash	32.9	34.8	26.8	32.5	29.6
Sulphate of magnesia	33.5	34.4	26.4	31.1	25.0
Sulphates of soda, potash and magnesia	34.7	35.9	26.9	35.0	31.8
	Straw, pounds				
None	2,820	2,450	2,130	2,080	1,880
Sulphate of soda	3,420	3,050	2,500	2,730	2,400
Sulphate of potash	3,440	3,340	2,760	3,190	2,860
Sulphate of magnesia	3,500	3,070	2,630	2,860	2,340
Sulphates of soda, potash and magnesia	3,640	3,430	2,870	3,410	3,110

The action of the sulphates of soda and magnesia is indirect. These salts attack the store of potash in the soil and render it soluble. The results in the above table show that for the period

of 1852-61 the yields favor these salts more than sulphate of potash, but for the period 1892-1901 the sulphate of potash shows to advantage. Should the use of the sulphates of soda and magnesia be continued the sulphate of potash will keep increasing in better yields. The soils that these experiments were conducted on were rich in potash or else the effect of the sulphate would be more noticeable.

The use of either sulphate of soda or magnesia is hardly to be considered on American soils except when some special crop is grown that depletes the soil of them, which is indeed very rarely. When fertilizers are used there is enough of these constituents supplied for the needs of the crop. Most of our soils are well furnished with these constituents. Common salt is cheaper than sulphates of soda or magnesia and when needed will serve the same purpose, namely, to render potash available.

Carbonate of magnesia is sometimes found on the market but carbonate of lime performs the same functions except that magnesia is not supplied, so that we need not consider this material in our fertilizer problems.

Ammonium chloride and ammonium carbonate are not good fertilizers because they injure plants. Ammonium chloride is sometimes called sal-ammoniac and in the pure state it is rather expensive.

Manganese Salts.—Manganese is found in small amounts in plants and it is said to stimulate their growth. Although this element is not necessary to apply as soils contain enough of it to satisfy the wants of the plant.

CHAPTER XI.

LIME, GYPSUM AND GREEN MANURES.

Lime has been used for agricultural purposes for many centuries, but for how long we do not know. Records show that it was used on land before the Christian Era. During the sixteenth and seventeenth centuries the practice of liming the land was common in Great Britain and at that time lime was one of the principal fertilizers and large applications were often supplied.

Forms of Lime.—Lime is obtained by burning limestone, chalk, or shells. These are all substances rich in carbonate of lime ($CaCO_3$). When they are burned the carbonic acid (CO_2) passes off, leaving the oxide of lime (CaO), which is called quicklime, caustic lime, store lime and burned lime. The oxide of lime is usually known as lime. When water is added to this product it is readily absorbed and high heat develops forming hydrate of lime ($Ca(OH)_2$) which crumbles to a powder. This is known as slaked lime. Quicklime readily absorbs water and therefore slakes when exposed to the air. This is known as air slaked lime and is not as completely slaked as when treated with water. Quicklime is apt to change to limestone on standing as it absorbs carbonic acid from the atmosphere. When quicklime is applied to the soil it changes to carbonate of lime.

The forms of lime may be represented as follows:

Calcium carbonate—$CaCO_3$	Limestone Chalk Shells
Calcium oxide—CaO	Lime Quicklime Stone lime Burned lime Caustic lime
Calcium hydrate—$Ca\ (OH)_2$	Water slaked lime Air slaked lime

One hundred pounds of limestone makes about 50 to 56 pounds of quicklime which produces about 75 to 85 pounds of

water slaked lime. The purer the limestone, the more quicklime and water slaked lime is obtained.

Sources of Carbonate of Lime.—The principal sources of carbonate of lime in the United States are marble lime, magnesian limestone (Dolomite) and oyster shell lime.

Marble lime is one of the purest of limestones and when burned produces a fine white quicklime.

The magnesian limestone is one of the most prevalent in the Eastern part of the United States. It contains considerable magnesium carbonate, which, though valuable, is not equal to lime.

Oyster shells are pure carbonate of lime but are hardly ever clean, and so the lime obtained by burning oyster shells is not as valuable as that obtained from marble lime.

Lime should be purchased on its composition because lime from one source may contain much more actual lime than from another.

COMPOSITION OF LIMESTONE.[70]

	A	B	C	D	E
Lime	55.14	54.22	54.46	31.70	30.46
Magnesia	0.14	0.35	0.60	20.25	21.48
Silica and insoluble	1.10	2.46	1.80	1.60	0.08
Oxides of iron and aluminum	0.11	0.28	0.15	0.28	0.25
Carbonic acid	43.51*	42.69*	42.99*	46.17*	47.73
	100.00	100.00	100.00	100.00	100.00

	F	G	H	I	J	K
Lime	31.31	52.09	27.78	36.03	28.96	56.02
Magnesia	21.01	0.47	16.63	17.76	18.54	—
Silica and insoluble	0.48	4.11	4.21	4.00	9.98	0.15
Oxides of iron and aluminum	0.20					
Carbonic acid	47.00	†	†	†	†	43.83
	100.00					100.00

* By difference. † Undetermined.

A is selected limestone. B, bluish limestone, constituting the larger part of that at present quarried. C, granular limestone, impossible to burn in the ordinary kilns because it falls to pieces half as large as a pea when heated. D, pearl-colored stone from a small vein recognized by the eye as magnesian. E, analysis from U. S. Geol. Survey, 1898-9, pt. 6, p. 570. Analyses G to I, from Bulletin 6, Geol. and Hist. Survey Conn., p. 89. K is a white crystallized limestone. Analyses A, B, C, D, F, J and K, made at this same station.

Analyses of Carbonate of Lime Compounds.

	Pure limestone Per cent.	Pure magnesian limestone Per cent.	Coral[1] limes, Florida Per cent.	Coral[1] limes, Florida Per cent.
Lime	56.00	30.43	54.52	44.69
Magnesia	—	21.74	—	—

	Marl[1] New York Per cent.	Carbonate[1] of lime Per cent.	Ground[1] oyster shells Per cent.	Shell[1] lime Per cent.
Lime	49.93	35.69	25.24	41.99
Magnesia	—	—	—	—

[1] Connecticut Experiment Station.

Analyses of Stone Lime or Quicklime.[70]

	Adams, Mass. New process	Glen Falls, N. Y.	Glen Falls, N. Y.	Cheshire, Mass.
Lime	98.13	90.99	89.56	90.52
Magnesia	0.42	1.14	1.22	4.27
Other matters by difference	1.45	7.87	9.22	5.21
	100.00	100.00	100.00	100.00

	Vermont	Housatonic av. four analyses	E. Canaan Conn. Lime Co.	Lee, Mass	W. Conn. av. seven analyses
Lime	59.90	56.60	55.86	54.63	52.12
Magnesia	35.13	38.62	40.24	37.83	36.08
Other matters by difference	4.97	4.78	3.90	7.54	11.80
	100.00	100.00	100.00	100.00	100.00

Analyses of Slaked Lime, "Hydrated Lime."[70]

Lime	56.00	38.27	71.16	46.15[1]
Magnesia	3.94	25.84	—	32.70
Silica and insoluble	10.80		—	—
Oxides of iron and aluminum	1.20		—	—
Moisture	8.70	35.89	—	21.15
Combined water and other matters by difference	19.99		28.84	—
	100.00	100.00	100.00	100.00

[1] Not completely slaked, contains some quicklime.

ANALYSIS OF AIR SLAKED LIME.[70]

Silica and insoluble	4.42
Oxides of iron and aluminum	1.11
Lime	45.82
Magnesia	33.30
Other matters	15.35
	100.00

When Soils Need Lime.—A certain amount of calcium carbonate should be present in soils as this compound helps to make plant food available and keeps the soil in a condition favorable for producing crops. When there is a deficiency of calcium carbonate, the soil will most likely be acid or sour. Most farm crops do not grow well on sour soils, but certain weeds seem to thrive on them, and so it is important to keep soils sweet or stocked with a sufficiency of carbonate of lime. The addition of ordinary fertilizers will not benefit crops on sour soils because the nitrifying organisms cannot work to advantage in an acid medium. There may be an ample supply of nitrogen, phosphoric acid and potash in a sour soil and yet good crops cannot be produced because of the need of lime. Soils that run as low as 0.2 per cent. of calcium carbonate generally need lime.

How to Find Out When Soils are Acid.—A simple method that is often effective consists of testing the soil with blue litmus paper. A few cents worth of this paper may be purchased at a drug store. Test the soil as follows: Collect some earth from those portions of the field where the plants are poor or sickly. Mix the samples of earth together, take a small portion and add water to form a paste. Place one end of the litmus paper in this mixture and let it remain for about 45 minutes. If the soil is sufficiently acid the color of that part of the litmus paper which was dipped in the paste will be changed to red. This is not a delicate test and is only an indication of a soil badly in need of lime. Another way to find out whether your soil needs lime is to express about one-half a pound of the suspicious soil to your State Experiment Station requesting them to find out if your soil needs lime. Or a plot of the

suspicious land may be spread with a liberal application of lime and the effect on the crop noted. This last method is perhaps the best test.

How to Apply Lime.—Finely ground limestone, quick-lime, or water slaked lime may be used to correct acidity in soils. If water slaked lime is used it should be applied just as soon as it becomes powdered. If quick-lime is preferred, it may be dumped into small heaps and kept covered with earth until the lime slakes or crumbles.

Lime should be spread in a thin even layer and harrowed in. If slaked lime is used it should be harrowed in immediately as it changes to the carbonate form on exposure to the air. Some farmers use a lime spreader which machine is very effective. Lime should be applied some time before planting as it is liable to injure the seed.

The Form of Lime to Use.—Marble dust, ground limestone, ground oyster shells, etc. (calcium carbonate), are preferable for soils rich in organic matter, to prevent the loss of nitrogen. Should you desire to correct the acidity of a soil and decompose the organic matter quickly, caustic lime or slaked lime should be used.

The Pennsylvania Experiment Station conducted experiments using a four year rotation of corn, oats, wheat and hay with applications of slaked lime at the rate of two tons per acre every four years, and of ground limestone at the same rate every two years. Four sets of plots were employed so that each crop was grown every year.

EXPERIMENTS WITH SLAKED LIME AND LIMESTONE.[19] TWENTY YEARS' PRODUCE PER ACRE.

Soil treatment	Corn		Oats		Wheat		Hay Tons (19 yr.)
	Grain Bus.	Stover Tons	Grain Bus.	Straw Tons	Grain Bus.	Straw Tons	
No lime	819	18.8	678	14.3	279	13.2	24.9
Slaked lime	699	16.5	617	17.8	318	14.6	23.6
Ground limestone	798	18.6	733	20.4	331	16.6	29.2

The foregoing results show that the ground limestone produced the larger yields. A determination of the nitrogen content in the surface soil to a depth of 9 inches, at the end of sixteen years, showed that the plots that received limestone contained 2,979 pounds of nitrogen per acre and the slaked lime plots, 2,604 pounds of nitrogen, or a difference of 375 pounds of nitrogen in favor of the limestone.

The Maryland Experiment Station experiments, covering eleven years, with carbonate of lime and caustic lime show that the carbonate of lime gave the better results. A rotation of corn, wheat, and mixed hay(clover and timothy) was grown on plots that received 1,400 pounds of caustic lime and equivalent amounts of shell marl and ground oyster shells at the beginning of the experiment.

Maryland Experiments with Lime.[19]

Kinds of lime used	Produce in eleven years		
	Corn Bushels 4 crops	Wheat Bushels 3 crops	Hay Tons 4 crops
None	98	32	2.60
Caustic lime burned from stone[1]	128	32	3.09
Caustic lime burned from shells[1]	129	34	3.82
Calcium carbonate in ground shells	148	42	3.97
Calcium carbonate in shell marl	145	43	4.29

[1] Average of two plots.

Amount of Lime to Apply.—The nature of the soil regulates to a certain extent the amount of lime to apply. On soils that are acid it should be understood that the rains have carried the acidity to the subsoil. Therefore during dry periods the capillary water will bring up acid from the subsoil. Enough lime should be added to correct the acidity of the surface soil and allowance should be made for that which may be brought up from the subsoil. A small application will not last as long as a large quantity

but will in all probability give greater profits per ton of lime. If land must be improved quickly, large applications are the most desirable. The nature of the crops grown should also determine the amount of lime to use. On sandy soils 800 to 1,000 pounds of slaked lime or 1,600 to 2,000 pounds of ground limestone per acre should prove sufficient and for heavy clay soils, 1,600 to 2,000 pounds of slaked lime or 3,000 to 4,000 pounds of ground limestone per acre will prove beneficial. Sometimes smaller or larger amounts are used with good results. Some farmers use light applications every four or five years while others apply large quantities at eight, ten or fifteen year periods. The farmer should be the best judge and he can find out after one trial the amount of lime necessary to satisfy his conditions and when to apply it.

Amount of Lime Removed by Crops.—The table on page 235 shows the amounts of lime removed by ordinary field crops.

The leguminous crops, peas and clover, remove more lime than the grasses. Straw is richer in lime than the grain and seeds. The root crops contain considerable lime and the leaves or tops remove more than the roots. The sugar beet is especially rich in lime. Cabbages and tobacco contain a great deal of this constituent.

Legumes Require an Alkaline Soil.—It is a well known fact that alfalfa, clovers, etc., require a soil well supplied with lime for the best returns. One has only to visit an alfalfa field in a limestone section to find out the benefit of an alkaline soil for producing leguminous crops. On acid soils the legumes become sickly and do not develop tubercles or nodules on their roots. These helpful bacteria which gather nitrogen from the air are not active in an acid soil and cannot perform their functions.

Amount of Lime in Soils.—The amount of lime in soils varies with the region, nature of the crop grown, kind of soil, and general use of the land.

AMOUNTS OF LIME AND WEIGHTS OF ORDINARY CROPS IN POUNDS PER ACRE.[37]

	Wt. as harvested	Lime
Meadow hay, 1½ tons	3,000	30.4
Timothy hay, 1½ tons	3,000	14.3
Clover hay, 2 tons	4,000	81.1
WHEAT		
Grain, 25 bus.	1,500	0.9
Straw	2,500	7.0
Total	4,000	7.9
RYE		
Grain, 30 bus.	1.680	0.9
Straw	2.000	6.8
Total	3.680	7.7
OATS		
Grain, 50 bus.	1,600	1.6
Straw	2,100	9.5
Total	3,700	11.1
BARLEY		
Grain, 50 bus.	2,350	1.4
Straw	2,800	9.2
Total	5,150	10.6
CORN		
Kernel, 50 bus.	2,800	0.80
Cobs	700	0.02
Stover	2,300	11.50
Total	5,800	12.32
POTATOES		
Tubers, 200 bus.	14,000	3.0
Haulm, (stems)	4,500	28.1
Total	18,500	31.1
SUGAR-BEETS		
Roots, 20 tons	40,000	12.6
Tops	20,000	99.2
Total	60,000	111.8
MANGELS		
Roots, 25 tons	50,000	12.9
Tops	18,500	27.5
Total	68,500	40.4
TURNIPS		
Roots, 20 tons	40,000	32.3
Tops	11,600	59.5
Total	51,600	91.8
SWEDES		
Roots, 16 tons	32,000	21.5
Tops	4,800	23.1
Total	36,800	44.6
Cabbages, 20 tons	40,000	95.3
Onions, 500 bus,	28,500	42.7
Tobacco, leaf	1,500	83.4

PERCENTAGE OF LIME IN VARIOUS SOILS.[37]

	Kind of Soil	Lime
1.	Prairie soil from North Dakota	0.85 to 3.9
2.	Virgin soil from Walla Walla; fertile, sandy, from basaltic rock	1.34 to 2.1
3.	Heavy prairie swamp, with clay subsoil; yields large crops of hay, fair wheat, poor corn	1.39
4.	Muck, from Union Pier, Michigan	0.97
5.	Subsoil corresponding to No. 3	1.28
6.	Drift soil, with clay subsoil, Oswego, N. Y	0.35 to 1.87
7.	Alluvial bottom soil, Louisiana	0.41 to 2.06
8.	Barren, pine hill land, Louisiana	0.09
9.	Sandy soil, Rio Grande, N. J	0.225 to 0.505
10.	Soils from Kansas and Nebraska, prairie	0.45 to 0.76
11.	Sugar-cane soil, Demerara, cropped 15 years	0.08
12.	Sugar-cane soil, Jamaica	0.99
13.	Rhine alluvium, Zuider Zee, Holland, highly fertile — surface	4.09
	— 15 in. deep	5.10
	— 30 in. deep	2.48
14.	Fertile wheat soil, Mid Lothian, Scotland	1.23
15.	Sterile soil, Upper Palatinate, Bavaria	0.10
16.	Ten sandy soils from Alabama, Florida and Georgia	0.045 to 0.141
17.	Ten clay soils from Alabama, Georgia, South Carolina, Mississippi, Tennessee and Louisiana	0.036 to 3.054
18.	Average of 466 non-calcareous soils of humid region of the United States (S. C., N. C., Ark., Ky., and Gulf States)	0.11
19.	Average of 313 soils of arid region of the United States (Cal., Wash., Montana)	1.36
20.	Alkali soils of California, Washington and Montana	0.03 to 4.5
21.	Black tschernosem, Poltara, Russia (wheat soil)	1.21
22.	Volcanic soil, gray, Sumatra (tobacco soil)	0.77
23.	Granitic soil, Granville, N. C. (yellow tobacco soil)	0.07
24.	Limestone soil, Donegal, Penna	0.61
25.	Limestone soil, Rocky Spring, Penna., surface	0.41
26.	Limestone soil, Rocky Spring, Penna., subsoil	0.25

The foregoing analyses do not show the great variation of lime in soils, for chalky soils, coral soils, marly soils, etc., contain sometimes as high as 25 per cent. of lime. The analyses in the table show that the fertile soils contain 0.2 per cent. of lime or more, and those containing less than this amount are not very productive.

Mechanical Action of Lime.—On a heavy clay soil lime loosens the soil and makes it lighter and more porous. It relieves some-

what the tendency of these soils to puddle. It renders them easier to work and lessens the stickiness or adhesiveness a great deal. We learned that puddling is due to the fine state of division of the particles in clay soils. Lime tends to cause a coagulation or flocculation of these fine soil particles. This action is easily demonstrated by placing some clay soil in a glass of water and adding a pinch of lime. When the lime is added and the contents of the glass well stirred, the soil particles precipitate and settle to the bottom of the glass leaving a clear solution of water.

Lime lessens the tendency of clay soils from cracking because it does not shrink in dry weather. For this reason the addition of lime to clay soils makes them easier to work. On sandy soils lime has an entirely opposite effect than on clay soils. Instead of making the soil lighter and more open it binds together the soil particles. It increases the capillary power of light soils and thus makes these soils better able to stand dry weather.

Lime Renders Plant Food Available.—We have already said that lime acts on organic matter. On peaty land, old forest land, and other places where considerable vegetable matter has accumulated, lime is very beneficial as it helps to liberate the nitrogen and form nitrates. The following table shows the effect of lime on a soil that was heavily supplied with organic matter.

EFFECT OF LIME ON SOILS RICH IN ORGANIC MATTER.[9]

Year	Artificial fertilizers	
	With 1 ton lime per acre	With no lime
1895	100	70
1896	100	84
1897	100	80
1900	100	81
1901	100	90

The yield of the limed plot is taken at 100, and it is evident that the liming of land heavily supplied with organic matter is beneficial in crop production.

Most soils contain iron and alumina which are united with more or less phosphoric acid. These phosphates are very slowly

soluble in soil solutions and an addition of lime liberates some of the phosphoric acid by combining with a part of the iron and alumina phosphates.

The inert potash compounds in soils, as silicates which are insoluble, are attacked by lime and the potash set free, because lime changes place with the potash in these substances.

Boussingault shows the effect of lime on increasing the potash content of clover.[68]

	Kilos per hectare [1]			
	Unlimed		Limed	
	1st year	2d year	1st year	2d year
Lime	32.2	32.2	79.4	102.8
Potash	26.7	28.6	95.6	97.2
Phosphoric acid	11.0	7.0	24.2	22.9

The limed plots show about three and one-half times more potash than the unlimed and an average of about two and one-half times more phosphoric acid.

Lime does not add any nitrogen, phosphoric acid or potash to the soil but sets these constituents free. Therefore the continual use of lime will make a soil less productive, hence the saying, "Liming makes the father rich and the son poor."

Lime Decreases Many Fungus Diseases.—Many fungi and moulds that prosper in an acid soil are destroyed when lime is added and the soil kept alkaline or sweet. Certain rusts, smuts, club root, etc., are due to fungi that require a sour soil for their development. Lime seems to favor the potato scab fungus and potatoes grown on limed soils usually produce scabby tubers. This fungus may be checked in alkaline soils by dipping the seed potatoes in a solution of formalin or corrosive sublimate before planting.

Acidity of Upland Soils.—The Rhode Island Experiment Station has conducted extensive and valuable experiments on the need of lime for soils and the following is a summary of an article "Acidity of Upland Soils" from one of this Station's reports.

[1] Kilo = 2.20 pounds; hectare = 2.47 acres.

The removal of plants from the soil and the use of certain fertilizers doubtless exhaust the lime and other basic ingredients of the soil more rapidly than would be the case were nature allowed to take her course.

That an acid condition is liable to result in consequence of the above-mentioned operations, particularly in the case of soils derived from rocks deficient in basic ingredients, we believe to be a reasonable assumption.

A strongly marked reddening of blue litmus paper seems to be a simple and effective indication of the condition of a soil in the above-mentioned particulars.

The value of a satisfactory method for determining the relative acidity of soils would seem to be great.

A dangerous degree of acidity or at least a fatal lack of carbonate of lime appears to exist in upland and naturally well-drained soils, and is not confined to muck and peat swamps and very wet lands as most American and many other writers seem to assume, in view of which it appears that the test for acidity should be more generally applied to such soils.

That this condition of upland soils has not been more fully recognized heretofore is not surprising for the reason that the failure or partial failure of certain crops has been attributed to winter-killing, poor germination of seeds, drought, excessive moisture, or attacks by insects or fungi. Upon soils where certain plants are injured only to a limited extent by acidity others would be expected to thrive best of all, in consequence of which it is not surprising that the cause for the partial failure of certain crops upon them has not been suspected.

The inefficiency of land plaster as compared to air slacked lime in the culture of beets and in overcoming the ill effect of sulphate of ammonia, as well as the highly beneficial results from the use of caustic magnesia and carbonate of soda, all tend to further strengthen the position that the fault of the soil in question is a lack of basic ingredients, to which the presence of noxious compounds which may partly or wholly give rise to the acid reaction, is attributable.[71]

Observations on the Growth of Plants.—The Rhode Island Experiment Station gives the following observations on the growth of plants:

1. The experiments with grasses show that they vary almost as widely as other plants, so far as concerns the effect of lime upon them.

2. Of the grasses tested, Kentucky blue grass and timothy seem to be most benefited by liming, and Rhode Island bent and red top most indifferent to it.

3. Awnless brome grass, meadow oat grass, tall fescue and orchard grass, which are among the most promising of the other grasses tried, all show a decided benefit from liming.

4. These results serve to explain why, on many of our Rhode Island soils, timothy 'runs out' quickly, and red top and Rhode Island bent persist better.

5. Without doubt many failures of timothy attributable to poor seed, or failure to 'catch' without definitely known cause, could have been prevented had the land been adequately provided with lime in the form of slacked lime or wood ashes.

6. One of the miscellaneous plants which has shown an injury from lime applied shortly before it has been grown, and which has failed to be benefited by it after it had lain in the soil long enough to lose its caustic property, is the lupine, but this plant has never been grown to any extent in Rhode Island.

7. The watermelon seems thus far to be about the only plant which is frequently grown here which may not be benefited eventually by liming.

8. Potatoes have sometimes produced a slightly greater total yield from liming, and usually a much greater percentage of merchantable tubers, but owing to the fact that wood ashes and water—or air slacked lime (not gypsum or land plaster) increase the virulence of the potato scab to a serious degree, lime in these forms, if used at all on potato fields, should be applied in small quantities, seldom exceeding half a ton per acre. The seed tubers should also be as free as possible from the scab, and be treated with corrosive sublimate solution, or with formalin.

9. Since potatoes, Indian corn, rye, Rhode Island bent grass and red top are less in need of lime than timothy, clover, barley, etc., certain fields could be set aside for rotations without lime and others with it.

10. Beets have shown a wonderful benefit from liming, not only on the Station farm but in many other sections of the State where experiments with them have been tried.

11. Spinach has again shown great benefit from liming, it being in this particular instance like lettuce.

12. Rye, dandelions (excepting the first crop in the spring), carrots and crimson clover have shown a less marked benefit from liming than beets and spinach.

13. Lupines which are grown so extensively for green manuring in Germany, but which are unsafe as feed until a poisonous substance has been extracted from them, are seriously injured by liming.

14. In regard to small fruits, orchard fruits and forest trees, little can be said at this time except that grapes (particularly the Delaware), peach and elm and American linden trees and quince bushes, seem to be benefited by liming. Possibly the white birch and Norway spruce may be injured by liming, even on a very acid soil. Blackberries were apparently very thrifty on the unlimed sulphate of ammonia plot, where many plants are wholly unable to endure the soil conditions.[72]

Effect of Lime in Conjunction with Nitrate of Soda and Sulphate of Ammonia.

Strawberries appear to have been helped by lime on our very acid soil, but it is possible that on a neutral or alkaline one injury from its use might result.

Asparagus has been wonderfully helped by lime. The superiority of nitrate of soda, as compared with sulphate of ammonia for this plant, was also most striking, affording a strong contrast, in this particular, with blackberries.

Rhubarb was apparently helped by lime, though in a small degree as compared with asparagus. Nitrate of soda also proved slightly more effective than sulphate of ammonia as a source of nitrogen.

White mustard showed moderate benefit from liming, and indicated the superiority of nitrate of soda as a form of nitrogen.

Parsley showed little if any advantage from the use of lime in connection with nitrate of soda, though on the unlimed sulphate of ammonia plot the results were extremely poor as compared with those where lime was applied. Comparing the two limed plots, but little difference in the two forms of nitrogen was noticeable.

Swiss chard, like beets, to which it is closely related, was wonderfully helped by lime, and gave far better results with nitrate of soda than with sulphate of ammonia.

Chicory was not helped, but, on the contrary, apparently injured by lime upon the nitrate of soda plots. Where sulphate of ammonia has been used continuously lime was, however, useful. Sulphate of ammonia gave better results than nitrate of soda on the limed plots.

Leeks were helped by lime in a most striking degree, even upon the nitrate of soda plots. For this crop the superiority of nitrate of soda as compared with sulphate of ammonia, even upon the limed plots, was also marked.

Endive plants were materially helped by lime, though in a less degree than asparagus or Swiss chard. These plants showed marked ability to withstand the conditions upon the unlimed sulphate of ammonia plot where leeks and Swiss chard failed utterly. Nitrate of soda gave better results than sulphate of ammonia upon the limed plots, though the difference was less striking than in the case of many other plants.

Carrots have indicated, usually, varying benefit from liming upon our quite acid soil, but upon a neutral or alkaline one, heavy applications might exert injury.

It would seem to be wise to introduce this crop into a rotation two or three years after liming, an idea which is suggested by occasional injury noticed soon after lime was applied.

Mangel-wurzels fully corroborated the experience of previous years, showing striking benefit from the use of lime, and great superiority of nitrate of soda over sulphate of ammonia when nitrogen in these forms is employed in like amounts and under identical conditions.

Watermelons give indication that the great injury otherwise resulting from liming can probably be avoided if the melons are introduced into the rotation three or more years after the lime is applied.

This season nitrate of soda proved, when used without lime, but slightly better than sulphate of ammonia, though on the limed plots the nitrate form of nitrogen was much superior.

Muskmelons have fully agreed with the tests of former years, indicating great benefit from liming, and the superiority of nitrogen in the form of nitrate of soda.

Dwarf broom-corn was helped moderately by liming, and on the limed plots the results were identical in the case of both forms of nitrogen.

Comet aster ("The Bride"), though it was helped by lime, even in connection with nitrate of soda, showed, nevertheless, wonderful ability to withstand the acid condition existing on the unlimed sulphate of ammonia plot where so many other kinds of plants entirely failed. But little difference was noticed between the action of the two forms of nitrogen.

Sweet peas showed marked advantage from the employment of lime, as shown by the increased weight of vines, and especially by the great increase of blossoms. Many more blossoms and heavier vines were produced by nitrate of soda than by sulphate of ammonia upon the limed plots.

Poppies seemed to be wonderfully helped by lime, as indicated by the number of blossoms and by the total weight of the plants. Nitrate of soda proved far superior to sulphate of ammonia as a source of nitrogen for this plant.[73]

Gas lime is the refuse lime from the manufacture of coal gas. Coal gas is passed over fresh slaked lime which absorbs the impurities, principally sulphur compounds and gases, from the coal gas. The presence of sulphur compounds in this product makes it unsafe to use because it has a poisonous effect on young plant growth. It may be applied to the soil provided it is allowed to thoroughly oxidize (by exposing it to the air for a long time in heaps mixed with earth) in which case the injurious compounds are changed so that they are not harmful.

Sometimes it is put on the land before being oxidized to get rid of insects and if so it should be applied a long time before planting.

ANALYSES OF GAS LIME.[9]

	Fresh	Slightly oxidized	Oxidized
Water	19.2	32.3	30.1
Calcium hydrate (slaked lime)	15.1	17.7	32.6
Calcium carbonate	24.2	44.5	17.5
Calcium sulphide	6.9	—	trace
Calcium thio-sulphide	11.8	12.3	—
Calcium oxy-sulphide	3.2	—	—
Calcium sulphite	1.5	14.57	20.2
Calcium sulphate	0.25	2.80	
Sulphur	4.3	5.14	—
Silica, etc	3.55	0.71	—

Gypsum.—This product is sometimes called land plaster. The lime is as sulphate in this compound.

ANALYSES OF GYPSUM.[56]

Source	Water	Lime	Magnesia	Sulphuric acid	Carbonic acid	Insoluble matter, etc.
Nova Scotia	6.45	33.74	0.75	44.87	—	5.79
New York	13.27	30.00	4.66	32.50	8.20	9.83

Gypsum does not contain as much lime as good limestone. It is a good fertilizer for leguminous crops as clover, alfalfa, etc. When applied to the soil the calcium sulphate attacks the insoluble potash and renders it available to plants. Boussingault shows this as follows:

COMPOSITION OF CLOVER ASH.[9]

	Without gypsum	With gypsum
Potash	23.6	35.4
Soda	1.2	0.9
Magnesia	7.6	6.7
Lime	28.5	29.4
Oxides of iron and manganese	1.2	1.0
Chlorine	4.1	3.8
Phosphoric acid	9.7	9.0
Sulphuric acid	3.9	3.4
Silica	20.0	10.4

The potash in the ash of clover when gypsum was used is much higher than without. The sulphuric acid and lime are practically the same.

The use of gypsum instead of lime (CaO) is not to be recommended as the real value of gypsum is in liberating locked-up potash. Superphosphates contain gypsum and when they are used it would not be necessary to apply gypsum. Gypsum seems to keep the soil moist in dry weather by absorbing moisture from the air or conserving it in the soil. On soils low in potash, gypsum does not seem to be beneficial and when soils fail to respond to gypsum an application of potash may be needed.

Snyder states: "The indirect action of land plaster (gypsum) on western and central prairie soils in liberating plant food, particularly potash and phosphoric acid, is unusually marked. Experiments conducted in the laboratory have shown that small amounts of gypsum are quite active in rendering potash, phosphoric acid, and even nitrogen, soluble in the soil water. It is not the land plaster itself that furnishes the food, but it is the power that it possesses in making the mineral matters available that are already in the soil. Land plaster acts more as a stimulant and not as a direct fertilizer, and if not used to excess it will be a profitable fertilizer to use on these soils, especially to bring in grass and clover."[69]

Green Manures.—Any crop that is grown and plowed under in order to benefit the soil is called a green manure. A green manure may help the soil in any of the following ways:

1. By keeping up the humus supply by furnishing organic matter.

2. By improving the texture of soils, by making heavy soils lighter and sandy soils more retentive.

3. By utilizing the soluble plant food that would otherwise be lost if the land was left bare.

4. By ridding the land of many weeds and thus serve as a cleaning crop.

5. By bringing up plant food from the subsoil to the surface soil.

6. By using a leguminous crop the nitrogen content of the soil may be increased, by utilizing the nitrogen from the air.

7. By preventing the washing of soils, or erosion.

Classes of Green Manures.—There are many crops used as green manures and the section of the country determines to a great extent what crops to select. Green manure crops may be classified as leguminous and non-leguminous.

1. The leguminous green manure crops are those that have the power of securing nitrogen from the air and are represented in the clovers, cowpea, soy bean, alfalfa, vetches, velvet bean, Canada field pea, etc.

2. The non-leguminous green manure crops are those that draw on the soil entirely for their supply of food, and rape, rye, oats, buckwheat and mustard are examples of this class.

Of the leguminous crops the red clover is the most popular in the North and the cowpea and clovers in the South. Crimson clover and alfalfa are also popular. The vetches and soy beans are not used so much as the other mentioned legumes.

Rye is the most common non-leguminous crop and is often pastured in the fall or early winter.

Leguminous Crops are to be Preferred.—The leguminous crops are better than the non-leguminous because they can secure nitrogen from the air and increase the soil supply of this constituent. They also return more nitrogen to the soil when plowed under. The non-leguminous plants simply draw on the soil for food and when plowed under only add non-nitrogenous matter. The principal benefit derived from the non-leguminous plants is to save the loss of soluble plant food when a legume cannot be selected. The non-leguminous plants are more expensive to grow because they require a supply of nitrogen and generally of phosphoric acid and potash to insure good growth. The legumes only require potash and phosphoric acid and sometimes only phosphoric acid. So it is evident that rye, oats, rape, mustard, etc., cannot take the place of the legumes in supplying green manure as they cost too much to grow and do not return as much fertility to the soil.

Fertility Restored by Some Plants.—The following table shows the composition of some plants used as green manures and also gives an indication of the fertility added to the soil when they are plowed under.

COMPOSITION OF PLANTS (TOPS AND ROOTS)[19]. DELAWARE EXPERIMENT STATION: CROPS SEEDED JULY 22.

Crop and date of harvest.	Parts of plant	Pounds per acre and per cent. in roots.			
		Air-dry matter	Nitrogen	Phosphorus	Potassium
Cowpeas Nov. 7....	Tops..................	3,718	65.2	7.2	39.2
	Roots, 0 to 8 inches...	301	4.2	1.0	1.9
	Roots, 8 to 12 inches...	9	0.1	0.1	0.1
	Per cent. in roots....	8.0	6.0	13.0	8.0
Soy beans Nov. 11...	Tops..................	6,790	130.9	16.5	38.3
	Roots, 0 to 8 inches...	717	8.8	1.0	1.4
	Roots, 8 to 12 inches...	39	0.5	0.0	0.1
	Per cent. in roots....	10.0	6.5	5.5	4.0
Vetch Nov. 19...	Tops..................	3,064	108.0	9.8	65.1
	Roots, 0 to 8 inches...	584	12.8	2.0	5.7
	Roots, 8 to 12 inches...	16	0.4	0.1	0.2
	Per cent. in roots....	17.0	11.0	18.0	8.0
Crimson clover, Nov. 20...	Tops..................	5,372	128.2	25.9	69.7
	Roots, 0 to 8 inches...	381	5.7	0.8	3.2
	Roots, 8 to 12 inches...	32	0.5	0.1	0.3
	Per cent. in roots....	7.0	6.0	3.5	5.0
Alfalfa Nov. 20...	Tops..................	2,267	54.8	5.7	26.7
	Roots, 0 to 8 inches...	1,972	40.2	3.7	7.9
	Roots, 8 to 12 inches...	8	0.2	0.0	0.0
	Per cent. in roots....	47.0	42.0	39.0	23.0
Red clover Nov. 22...	Tops..................	2,819	69.8	8.3	38.6
	Roots, 0 to 8 inches...	1.185	32.5	4.3	8.0
	Roots, 8 to 12 inches...	27	0.7	0.1	0.2
	Per cent. in roots....	30.0	32.0	35.0	18.0
Rape Nov. 16...	Tops..................	5,533	116.2	18.3	123.0
	Roots, 0 to 8 inches...	864	13.2	2.2	10.9
	Per cent. in roots....	13.5	10.0	11.0	8.0

There is a great difference in the proportion of nitrogen, phosphoric acid and potash in the tops and roots of the above plants. The cowpea, soy bean, vetch, crimson clover, and rape especially contain a large proportion of nitrogen in the tops.

Although alfalfa contains more nitrogen in the tops, the amount in the roots is quite considerable and in a larger proportion than in the other legumes.

Crimson clover is higher in phosphorus and potassium than the other legumes.

Alfalfa contains less potassium than the other crops, and next to cowpeas, the smallest amount of phosphorus.

Rape uses a great deal of potash, especially in the tops.

Amount of Nitrogen Obtained from the Air.—The importance of using legumes when possible is emphasized by the amount of nitrogen that is fixed by bacteria from the air.

FIXATION OF NITROGEN BY ALFALFA IN FIELD CULTURE.[19]

Treatment applied	Dry matter in crops (Pounds)	Nitrogen in dry matter (Per cent.)	Nitrogen in crops (Pounds)	Nitrogen fixed by Bacteria (Pounds)
None	1,180	1.85	21.81	..
Bacteria	2,300	2.70	62.04	40.23
Lime	1,300	2.02	26.20	..
Lime, bacteria	2,570	2.65	68.02	41.82
Lime, phosphorus	1,740	2.03	35.40	..
Lime, phosphorus, bacteria	3,290	2.71	89.05	53.65

It should be known that the legumes do not necessarily draw all of their nitrogen from the air when soils are well supplied with nitrogen. On such soils the legumes may use the nitrogen in the soil instead of fixing the nitrogen from the air. Green manures are generally grown to increase the nitrogen supply in the soil so that on most farms where green manuring is practiced the nitrogen will be derived mostly from the atmosphere by the leguminous plants. Should organic matter be needed on a soil containing sufficient nitrogen, a non-leguminous crop may be grown.

The Best Time to Plow Under a Green Manure.—Crops used for green manuring should be plowed under before they become dry. When they are plowed under while green and fresh they are more readily decayed and prevent the loss of water somewhat from light soils. Dry crops plowed under interfere with the use of water from the subsoil and on light

sandy soils may lower the yield of the crop that follows. If possible the green manure should be plowed under some two or three weeks before planting time to give it a chance to partially decay so as not to injure the planted crop and to furnish some food for the young seedlings.

The Best Time to Grow a Green Manure.—If the soil is poor and run down it is sometimes advisable to keep it in a green manure for a season or two. Generally, however, green manures fit well into rotations and may often be grown when the land is ordinarily idle or between money crops. In the South, crops like rye, crimson clover, red clover, vetch, etc. may be grown in the winter and turned under in time for the summer crop. In the North, rye and vetch may be used as winter crops. Sometimes it is advisable to sow a green manure at the time another crop is laid by. Then when the crop is harvested the green manure crop will have grown sufficiently to turn under and the land may be sowed to some small grain crop; or the green manure crop may be planted after harvest and remain on the land all winter and plowed under in the spring.

In fruit orchards green manure crops (cover crops) as rye, oats, clover, etc., are often sown about mid-summer to absorb moisture and available plant food from the soil and to cause the buds to mature and cease growth of the wood and leaves. This crop is allowed to remain on the soil all winter and in the spring it is plowed under. By keeping the land covered during the winter leaching of plant food and washing away of soil is lessened.

Deep Rooted Plants Valuable.—Alfalfa, clover, etc., have very long tap roots which penetrate the subsoil, thus securing a great deal of plant food that would not be within reach of many cultivated plants. These leguminous plants also bring a great deal of plant food from the subsoil to the surface soil and leave it there for succeeding crops. When these deep roots decay they leave openings in the soil which help to increase drainage and aeration and thus improve the physical condition of soils.

CHAPTER XII.

COMMERCIAL FERTILIZERS.

Since 1860, when fertilizers were used on a comparatively small scale, the fertilizer industry has increased until to-day it is of great importance. In 1860 the wholesale cost of the output of the fertilizer factories was $891,344; in 1890, $39,180,844; in 1900, $40,445,661; and in 1905, $50,506,294 or a difference of $49,614,950 between the years 1860 and 1905. These figures do not represent what the consumer paid for fertilizer during these years as these amounts cover practically the wholesale cost. The above figures are only approximate at the best and in all probability they should be larger for the years 1900 and 1905, but they will serve to impress one with the magnitude of the fertilizer industry in the United States to-day.

STATISTICS ON FERTILIZERS.[74]

	1860	1890
Establishments	47	390
Hands employed	308	10,158
Capital	$466,000	$40,594,168
Wages	95,016	4,671,831
Materials	590,816	25,113,874
Products	891,344	39,180,844

STATISTICS ON FERTILIZERS, 1900-1905.[32]

	1900	1905
Permanent investments	$60,685,753	$69,023,264
Executive cost	5,451,153	6,490,727
Manufacturing costs	10,247,759	10,798,212
Cost of materials	28,958,473	39,343,914
Total cost of products (fertilizers)	40,445,661	50,506,294
No. of tons manufactured	2,887,004	3,591,771

From this last table it will be seen that 3,591,771 tons of fertilizers were manufactured during 1905. If the consumer paid on the average $25 a ton for his fertilizer, the total cost would be $89,794,275 or an amount equal to the annual sugar crop (beet and cane in the United States); or to the barley crop;

or to the rice, rye and flaxseed crops combined. As the consumption of manufactured fertilizers is increasing and considering that the tonnage for 1905 was greater by 704,767 tons than for 1900, and that the estimates are only approximate and probably too low, we may safely conclude that for the year 1910 over $100,000,000 was spent for fertilizers in the United States, or an amount equal to the oat crop for 1909.

Distribution of Fertilizer.—The following table shows the distribution of manufactured fertilizers used in some of the states for the year 1907.

CONSUMPTION OF FERTILIZERS BY STATES.[1]

Alabama	301,657
Arkansas	21,400
California	21,647
Connecticut	45,000
Delaware	15,000
Florida	107,226
Georgia	786,736
*Illinois	15,000
Indiana	118,000
*Kansas	5,000
Kentucky	48,000
Louisiana	102,454
*Maine	75,000
Maryland	180,000
*Massachusetts	85,000
Michigan	20,000
Mississippi	138,668
Missouri	15,000
*New Hampshire	42,000
New Jersey	130,000
*New York	300,000
North Carolina	459,181
Ohio	140,000
*Pennsylvania	300,000
*Rhode Island	12,000
South Carolina	631,033
Tennessee	37,798
Texas	21,600
Vermont	17,000
Virginia	237,018
West Virginia	22,105
Wisconsin	1,000
Total of	4,451,523

* Estimated.

[1] American Fertilizer Handbook. 1909.

It should be understood that there is considerable fertilizer used by other states not included in the above table but it is practically impossible to get complete data along this line. However it shows that most of the fertilizer is used by those states bordering on the Atlantic Ocean or near to it.

It is estimated that the consumption of fertilizers for 1908 was about 3 per cent. over 1907, and that the consumption for 1909 was about 15 per cent. more than for 1908.[1]

In the season of 1874-1875, Georgia used 48,648 tons of commercial fertilizer and for 1908-1909, 884,295 tons, or an increase of 835,647 tons. It is estimated that Georgia consumed about 1,000,000 tons for the year 1910. Should the other states and territories in the Union increase in the same proportion as Georgia, think of the enormous amount of money that will be expended for plant food in the future. Statistics show that the older states in the East and Southeast did not formerly use much fertilizer but the consumption in these states has been increasing every year until to-day it is very large. If our newer lands are treated in the same way as those in the East and Southeast, think of the large amount of fertilizer that will be necessary to produce profitable crops in the future.

Causes for the Large Consumption of Fertilizers.—The causes for the large and increasing use of commercial fertilizers are many. Single crop farming has caused many farms to run down in fertility. Money crops have been principally raised. Legumes have been grown occasionally or not at all. Green manuring has not been practiced enough. Poor drainage has caused losses of fertility. Some farms have lost much of their fertile soil by erosion. Farm manure has not always been saved and when saved it has not been preserved properly. According to Bulletin 140 by the Kentucky Experiment Station, it is estimated that the annual production of farm manure in the United States is equal in value to the corn crop at $1.05 per bushel, or nearly two and one-half billions of dollars. The most conservative estimate would put the waste of farm manure at one-third, an annual loss of about $800,000,000.00. This is about eight

[1] Ware Bros. Co., American Fertilizer.

times the amount spent annually in this country for commercial fertilizers. There is little wonder that so much of our soil is becoming unproductive. The crops have also been sold away from the farm instead of being fed to live-stock. Cover and catch crops have not always been grown. To sum up, we may say that the fertility of the soil has not been maintained, and farms that formerly yielded profitable crops with applications of 200 pounds of commercial fertilizer per acre, now require 400 to 600 pounds and sometimes 800 to 1,200 pounds to produce the same results.

With the market gardner and trucker conditions are different. The demand for vegetables in our large cities has caused the market gardner in the north and the trucker in the south to use heavy applications of fertilizers to produce profitable crops. Many of these crops are heavy feeders and require to be marketed or shipped as early as possible, as a few days often means a great difference in the prices received, and so high priced quick acting fertilizers are generally used. The truckers are often located on sandy soils of low fertility that must have plenty of fertilizer to produce money crops. The market gardner, who usually lives near or in a city or town, produces crops on lands that would bring a high price for building and other purposes, and can hardly ever afford to allow his land to be idle or to be sowed to some soil improving crop, but must have a money crop growing continually. The market gardner cannot afford to raise live-stock on such high priced land. So with the market gardner and trucker the consumption of fertilizer will increase with the demand for their products, and as the population of this country is increasing every year we may expect more artificial fertilizers to be used in producing market garden and truck crops. With these farmers, and especially the market gardner, the use of large quantities of commercial fertilizers is a necessity.

How the General Farmer May Lessen the Use of Commercial Fertilizers.—The consumption of commercial fertilizers may be reduced a great deal by many farmers. A better system of

farming should be adopted. A rational rotation system including money crops and soil improving crops should be practiced. Legumes should be included whenever possible in rotations to add to the supply of nitrogen and organic matter in the soil. Live-stock should be kept and the farm crops marketed through them. In this way a two-fold or full value will be obtained, namely, the feeding and fertilizer values. Farm manure should be saved and preserved. It should be saved to supply humus and fertility to the soil and it should be preserved to prevent losses of the essential elements by fermentation and leaching. The land should be well drained and tilled. Crops should occupy the land continually. Erosion must be prevented. Use commercial fertilizers only to supplement the organic matter and those constituents which should be contained in the soil. Fertilizers are not expected to produce crops alone, unless increased amounts are used every year. This is well illustrated by an experiment conducted at the Louisiana Experiment Station on corn. For four years commercial fertilizer only was applied to one plot and legumes and farm manure were used on another plot. The yield on the plot receiving commercial fertilizer alone, showed 12 bushels per acre and that on the plot receiving organic matter, 52 bushels, at the end of four years.

Fertilizing Materials Used by Manufacturers.—The fertilizing materials described in the previous chapters are those that the manufacturers draw on for making their mixtures. The farmer generally purchases his fertilizer in the mixed state under some brand name, as Corn Fertilizer, B. C. Brand, etc., which does not indicate the materials of which it is composed. The fertilizer materials usually predominate in one constituent while the manufactured fertilizers show usually two or three of the constituents, as nitrogen, phosphoric acid and potash. The manufacturers may employ materials that furnish large amounts of a particular constituent, as nitrate of soda, sulphate of ammonia, dried blood, sulphate of potash, muriate of potash, kainit, and Tennessee or Florida rock phosphate. He may choose some high grade materials as those just mentioned and some low grade materials as beet refuse, leather preparations, low grade

cotton-seed meal, soluble hair and wool waste, low grade bone-meal, etc. So when a mixed fertilizer reaches the farmer the identity of the materials of which it is composed is not known.

Approximate Output of the Fertilizer Factories.—To give an idea of the raw materials used by manufacturers in making up their brands, and the amounts, the following table is given. The data does not include all the fertilizer used in the United States but represents the output of the regular manufacturing plants as near as can be ascertained.[32]

Materials	1900		1905	
	Tons	Cost	Tons	Cost
Bones, ammoniates, etc.	168,510	$3,301,111	236,906	$2,807,336
Tankage, etc.	354,075	7,495,768	439,206	5,687,718
Fish products	28,977	183,542	58,437	880,412
Cotton-seed products	146,488	167,410	183,368	2,376,448
Ammonium sulphate	4,120	186,609	10,540	600,856
Sodium nitrate	17,203	625,501	40,234	1,677,761
Potassium nitrate	884	32,156	1,160	39,039
Phosphate rock	958,802	4,228,317	1,063,195	5,092,694
Kainit	54,700	520,833	190,493	1,891,073
Other potash salts	109,407	3,098,400	183,161	3,606,701
Wood ashes	..	..	342	2,050
Total	1,843,838	$19,839,647	2,407,042	$24,661,818
Sulphuric acid (50 Bé)	832,240	4,868,806	922,853	5,057,234
Dryers, sacks, etc.	210,926	4,250,020	261,876	9,624,862
Grand total	2,887,004	$28,958,473	3,591,771	$39,343,914

The following prices represent the actual average cost per pound for the ammonia, phosphoric acid and potash used in 1900 and 1905 in the raw materials employed in manufacturing fertilizers.[32]

	1900	1905
	Cents	Cents
Ammonia	10.06	10.34
Organic ammonia	12.60	15.00
Available phosphoric acid	2.14	2.05
Organic phosphoric acid	4.50	5.00
Actual potash	4.94	4 39
Organic potash	4.50	4.50

It should be noted that the prices used for the organic materials, practically all of which are credited at market prices, are somewhat higher than the average fertilizer raw material on factory account.

From these prices the actual cost for ammonia, available phosphoric acid and potash were calculated to be:

	1900	1905
Ammonia	$9,150,838	$11,594,232
Available phosphoric acid	11,954,492	12,464,062
Actual potash	3,647,673	5,660,758
Total	$24,753,003	$29,719,052

From the foregoing data we have:

Per ton of fertilizer	1900	1905
Average cost of ammonia	$3.17	$3.23
Average cost of available phosphoric acid	4.14	3.44
Average cost of actual potash	1.26	1.54
Average cost of dryers, sacks, etc.	1.46	2.74
Total	$10.03	$10.95

According to these figures the wholesale cost of a ton of fertilizer was $10.95 for the year 1905. This figure of course does not include anything but the cost of materials. The salaries of the executive force, the wages of the hands employed, the cost of running the machinery, insurance, travelling expenses, advertising expenses, office expenses, taxes, rent of land, interest on investment, and the many other considerations too numerous to mention, are not included in the above estimates.

Classification of Commercial Fertilizers.—We have learned that the manufacturers use the different fertilizer materials in making up their formulas. When these materials are mixed and put on the market, nitrogen, phosphoric acid and potash, nitrogen and phosphoric acid, phosphoric acid and potash, or any single one of the constituents may be present. Again, the manufacturers or other fertilizer dealers may sell some of the fertilizer

materials unmixed. As the manufactured mixtures are sold under many different brand names, and the unmixed fertilizer materials predominate in one or two of the essential elements, the chemist classifies them according to the constituents present.

Classification of Commercial Fertilizers.

1. Fertilizers furnishing nitrogen as the chief constituent.
   Nitrate of soda.
   Ammonium sulphate.
   Lime nitrate.
   Calcium cyanamid.
   Dried blood.
   Azotin.
   Concentrated tankage.
   Steamed horn and hoof meal.
   Cotton-seed meal.
   Linseed meal.
   Castor pomace.
   Nitrogenous guano.
2. Fertilizers furnishing phosphoric acid as the chief constituent.
   Double superphosphate.
   Superphosphate.
   Ground raw rock phosphate (floats).
   Bone ash.
   Bone-black.
   Basic slag.
   Phosphatic guano.
3. Fertilizers furnishing potash as the chief constituent.
   Sulphate of potash.
   Muriate of potash.
   Double sulphate of potash and magnesia.
   Potash manure salt.
   Kainit.
   Sylvinit.
   Potash-magnesia carbonate.
   Carbonate of potash.

4. Fertilizers furnishing nitrogen and phosphoric acid.

Tankage (bone and nitrogenous).

Fish fertilizers } raw and acidulated
Bone fertilizers }

Bat guano.

Peruvian guano.

5. Mixed fertilizers.

Nitrogenous superphosphates } factory mixtures
Special fertilizers }

Home mixtures.

6. Miscellaneous fertilizers.

Potassium nitrate.

Tobacco stems and stalks.

Wood ashes.

Cotton hull ashes.

Lime kiln ashes.

Brick kiln ashes.

Corn cob ashes.

Pulverized manures (sheep, poultry, pigeon, etc.).

Leather preparations.

Wool and hair waste (treated and untreated).

Fertilizers from beet molasses.

Fertilizers from wine lees.

Dried peat.

Marl.

Liquid fertilizers.

Flower fertilizers.

Shoddy (treated and untreated).

Soot.

Seaweed.

Sewage.

Ground feldsphatic rock (silicate of potash).

Manufacturing wastes, etc.

7. Indirect fertilizers—amendments.
   Ground limestone.
   Lime.
   Gypsum.
   Common salt (agricultural salt).
   Silicate of soda.
   Sulphate and carbonate of magnesia.
   Manganese salts.
   Iron sulphate.

The factory fertilizers coming under the class, "mixed fertilizers," are not sold under the names, nitrogenous superphosphates and special fertilizers. The manufacturers use attractive names for these fertilizers and these names are no indication of the composition and source of these mixtures. For example a nitrogenous superphosphate or a special mixture may be sold as Complete Potato Manure, Cotton King, Wheat Harvester, Golden Dust, Best Ever, Non Pariel, or any other name that suits the fancy of the manufacturer. This classification, as nitrogenous superphosphate and special fertilizer, is made by the chemist to cover all the factory mixed fertilizers whether they furnish nitrogen, phosphoric acid and potash, nitrogen and potash, or nitrogen and phosphoric acid.

Basis of Purchase of Fertilizers.—There are two systems used in purchasing fertilizers, namely, the unit system and the ton system.

1. **The Unit System.**—A unit is 20 pounds or one per cent. of a ton. Manufacturers and dealers in fertilizer materials use the unit system almost entirely. Tankage, bone products, blood, azotin, steamed horn and hoof meal, potash salts, nitrogenous salts, superphosphates, dry ground fish, raw rock phosphates, cotton-seed meal, castor pomace, etc., are all purchased on the unit basis. For example, muriate of potash will be quoted at 80 cents a unit. This means that the actual potash in muriate of potash will cost 80 cents for 20 pounds, or 4 cents for one pound. Dried blood perhaps will be quoted at $3.30 per unit of nitrogen. This means that 20 pounds of nitrogen in dried blood will cost $3.30, or 16½ cents for one pound.

In the unit system of purchasing and selling, the buyer and seller usually employ a competent neutral chemist to draw a representive sample of the material and settlement is made on the chemist's findings. This is indeed an excellent system because the buyer pays for just what is present in the material and the seller receives compensation for what his product contains. It may be said that this system is very satisfactory to the fertilizer trade.

2. **The ton basis** of purchase is the one commonly used by the manufacturer, dealer, etc., in selling to the consumer. The products, both mixed and unmixed, are sold to the consumer at a fixed price per ton of 2,000 pounds. This system is not as satisfactory as the unit system because the purchaser does not always receive a stipulated amount of the constituents contracted for. To be sure, the manufacturers guarantee their products to contain given amounts of fertilizer constituents and aim to meet or even to exceed their guarantees, but sometimes the fertilizers do not reach them in every particular. The prices of the fertilizers sold on the ton basis to the consumer do not usually fluctuate with the market, as the manufacturer tries to fix a price that will guard against loss, although many of them sell their fertilizers at times with very small and sometimes no profit when they have a large stock which they do not wish to carry over for another season.

Fertilizer Laws.—In order to protect the consumer and the

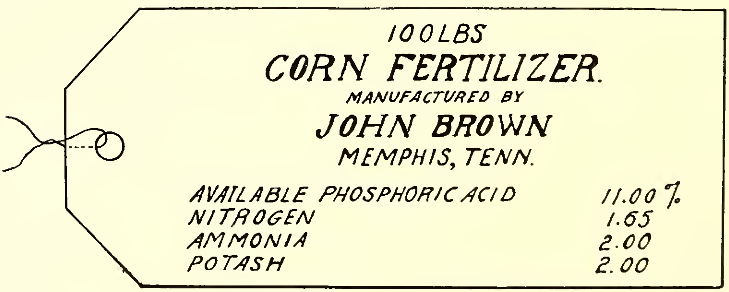

Fig. 22.—A fertilizer tag with guarantee.

honest manufacturer, several states have passed laws regulating

the sale of fertilizers. The enforcement of these laws is generally controlled by the Experiment Stations or the State Boards of Agriculture, through a staff of chemists and inspectors. The inspectors, who may or may not be chemists, draw samples of the various fertilizers, forward them to the laboratory, and the chemist analyzes them to find out if they are as represented. The results of the chemists' findings are published in bulletins or reports which are sent to the consumers, manufacturers, dealers, and other interested parties.

These laws require the manufacturers and dealers in fertilizers "to state what they sell and sell what they state." In other words they are compelled to guarantee their products. For example, The Smith Fertilizing Company are putting out a complete fertilizer, one that furnishes nitrogen, phosphoric acid and potash. Before The Smith Fertilizer Company can ship any of this fertilizer they must have printed on the bags, or on tags attached to the bags, the composition of the fertilizer, expressed by the minimum percentages of nitrogen, available phosphoric acid and potash, the weight of the package, the name, brand, or trade mark, and the manufacturer's or dealer's or jobber's name and address.

Let us suppose The Smith Fertilizer Company has the following statement printed on their sacks or on tags attached thereto.

THE SMITH FERTILIZER COMPANY

NEW ORLEANS, LOUISIANA.

CORN FERTILIZER.

Weight 100 lbs.

Guaranteed Analysis.

Nitrogen	1.65 per cent.
Ammonia	2.00 per cent.
Soluble phosphoric acid	8.00 per cent.
Reverted phosphoric acid	2.00 per cent.
Insoluble phosphoric acid	2.00 per cent.
Total phosphoric acid	12.00 per cent.
Available phosphoric acid	10.00 per cent.
Potash	4.00 per cent.

The name of the manufacturer, address, name of brand, weight of the package, and the amounts of the essential elements nitrogen, phosphoric acid and potash are given; therefore such a statement is the guarantee.

The weight of the package is a good requirement in fertilizer laws because the purchaser is able to tell just the amount contained in the package. The composition of the fertilizer enables the consumer to tell the amounts of fertilizer constituents he is buying. The guarantee then protects the consumer and prohibits the unscrupulous manufacturer from selling fertilizer not as represented in those states where fertilizer laws are enforced.

Comparison of Some of the Requirements of Fertilizer Laws.—The fertilizer laws in the several states are not all the same. They all agree on requiring,

1. The name of the manufacturer, dealer, jobber, or agent.
2. The address of the manufacturer, dealer, jobber, or agent
3. The name, brand or trade mark.
4. The weight of the package.

In the guaranteed chemical analysis there is not much uniformity in the requirements of different states. For example, one state will require the percentage of nitrogen and its equivalent in ammonia, another the nitrogen only, and still another will require the percentage of available nitrogen. Some require insoluble phosphoric acid; others do not. Some require a statement of available phosphoric acid; others state that the available phosphoric acid is not sufficient, but the soluble and reverted phosphoric acid must be given. Some require soluble potash; others require potash. Kansas and Illinois require the plant food to be guaranteed as elements (nitrogen, phosphorus and potassium) instead of as phosphoric acid and potash.

Some states require the sources of nitrogen, phosphoric acid and potash; others do not. Georgia does not allow fertilizers that are very wet or in a bad mechanical condition to be sold; some of the other states do not make this provision. Indiana requires that the names of the towns where the fertilizer is to be sold must be furnished the State Chemist. Some states require

that a stipulated weight of sample be drawn; others do not. Some states require that a duplicate sample be left with the party or parties where the sample is drawn. Some states do not allow the total amount of plant food to be lowered during the season in a given brand. They allow changing of the amounts of the constituents but the total plant food must not be lowered on any brand.

There is a great difference in other requirements of these laws. For example, some states exempt wood ashes, manures and marl from being licensed or tagged; others do not. Some states will not allow leather to be used; others do not stipulate that it cannot be used. Pennsylvania will not allow leather, hair, ground hoof or horn, wool waste, raw, steamed or in any form to be used in commercial fertilizer. Some states require that no fertilizer shall be sold that contains less than 12 per cent. of total plant food, when nitrogen is calculated as ammonia. Some states require all mixed fertilizers and acid phosphates to be sold with the names High Grade or Standard Grade printed on the sacks or tags, and that High Grade mixed fertilizers and acid phosphates shall contain at least 14 per cent. of total plant food, calculating nitrogen as ammonia, and Standard Grade shall contain, in all mixed fertilizers and acid phosphates, at least 12 per cent. of total plant food when nitrogen is calculated as ammonia; and less than 0.82 per cent. of nitrogen and 1 per cent. of potash cannot be sold in any High Grade or Standard Grade fertilizer. Massachusetts states that the retail prices per ton and the comparative commercial values may be published. Some states fine the manufacturer, jobber, or dealer when fertilizers fail to reach their guarantee and the fines vary with the laws. Some states sieze shipments when they are not guaranteed. Some states require a license tax, *i.e.,* a stipulated amount per brand per year. Indiana requires a license tax and a tonnage tax; that is, a brand tax and a tax on every ton or part of a ton sold. Many states require a tonnage tax. Georgia requires 10 cents a ton tax, while Louisiana stipulates 25 cents a ton. Louisiana has 12 to 15 inspectors on the road all the time who draw the samples. Many other states send out inspectors at certain times

of the year who draw the samples wherever they can get them. In Louisiana the manufacturer, dealer, or jobber must notify the chief inspector when and where he ships his fertilizers. There are many other variations in the state fertilizer laws, almost too numerous to mention in this discussion.

Model Fertilizer Law.—On account of the variations in the requirements of the several state fertilizer laws, the following law was adopted by the Association of American Agricultural Colleges and Experiment Stations.

This law requires the plant food to be stated as elements nitrogen, phosphorus and potassium instead of phosphoric acid and potash.

An ACT to prevent fraud in the manufacture and sale of commercial fertilizers.

Section 1. Be it enacted by the people of the State of——— represented in the General Assembly: That any person or company who shall offer, sell, or expose for sale, in this State any commercial fertilizer, the price of which exceeds five dollars a ton, shall affix to every package in a conspicuous place on the outside thereof, or furnish to the purchasers of goods sold in bulk, a plainly printed certificate, naming the materials, including the filler (if any), of which the fertilizer is made, stating the name or trade mark under which the article is sold, the name of the manufacturer and the place of manufacture, and a chemical analysis, stating only the minimum percentages of nitrogen in available form, of potassium soluble in water, of phosphorus in available form (soluble or reverted), and of insoluble phosphorus, the analyses to be made in accordance with the methods adopted by the Association of Official Agricultural Chemists of the United States.

Section 2. Before any commercial fertilizer is sold, or offered for sale, the manufacturer, importer, or party who causes it to be sold, or offered for sale, within the State of——shall file in the office of the———State Board of Agriculture, a certified copy of the certificate referred to in Section 1 of this ACT, and shall deposit with the secretary of the said Board of Agriculture

a sealed glass jar, containing not less than one pound of the fertilizer, accompanied with an affidavit that it is a fair average sample.

Section 3. The manufacturer, importer, or agent of any commercial fertilizer exceeding five dollars per ton in price, shall pay, annually, a license fee of twenty-five dollars for each one thousand tons (or fraction thereof) of said fertilizer, for the privilege of selling or offering for sale, within the State, during the calendar year, said fee to be paid to the treasurer of——— State Board of Agriculture: *Provided,* that whenever the manufacturer or importer shall have paid the license fee herein required, any person previously certified to the Office of the State Board of Agriculture to be an authorized agent for such manufacturer or importer shall not be required to pay the fee named in this section.

Section 4. All analyses of commercial fertilizers sold within the State, shall be under the direction of the State Board of Agriculture, and paid for out of funds arising from license fees, as provided for in Section 3. At least one analysis of each fertilizer shall be made annually, from a sample collected in open market.

Section 5. Any person or party who shall offer or expose for sale any commercial fertilizer without complying with the provisions of Sections 1, 2, and 3 of this ACT; or shall permit an analysis of such fertilizer to be furnished, stating that it contains a larger percentage of any one or more of the constituents named in Section 1 of this ACT, than it really does contain, shall be fined not less than two hundred dollars for the first offense, and not less than five hundred dollars for every subsequent offense; and the offender, in all cases, shall also be liable for damages sustained by the purchaser of such fertilizer: *Provided, however,* that a deficiency of one-half per cent. of the nitrogen, potassium, or phosphorus claimed to be contained, shall not be considered as evidence of fraudulent intent.

Section 6. Suit may be brought for the recovery of fines or damages under the provisions of this ACT, in the county where

the fertilizer was offered for sale, or where it was manufactured; and all fines so recovered, shall be paid into the treasury of the State Board of Agriculture by the court collecting the same. The treasurer of the State Board of Agriculture, after payment of expenses for collecting and analysis, and the publication of the annual report relating to the analysis, use, and results obtained from fertilizers, shall on or before the first day of July pay into the treasury of the State any surplus remaining in his hands, on account of license fees and fines, received during the previous calendar year through the provisions of this ACT.

Section 7. The———State Board of Agriculture shall publish, annually, a correct report of all analyses made and certificates filed, together with a statement of moneys received on account of license fees and fines, and expended for analyses and publication of the report relating to fertilizers.

Section 8. The officers and members of the———State Board of Agriculture or any person authorized by said board is hereby empowered to select from any lot or package of commercial fertilizers exposed for sale in any county of———, a quantity not exceeding two pounds, which quantity shall be for analysis to compare with the sample deposited with the secretary of said Board of Agriculture, as provided for in Section 2 of this ACT, and with the printed certificate described in Section 1.

Section 9. All suits for the recovery of fines, under provisions of this ACT, shall be brought by the Attorney-general of the State in the name of the people of the State of———.[19]

Comments on this Law.—The committee on fertilizer legislation, of the Association of Official Agricultural Chemists, make the following statements, in Bul. 116, Bureau of Chemistry:

It is evident, however, that there would be many points of dispute, not only between the officials of the various States respecting the proper method of tagging and of expressing analytical results, but also a still wider disagreement between the State Officials and the manufacturers. It seems, therefore, unwise to press the subject of national legislation in regard to fertilizers further until the officials of this association, representing as

they do the majority of States exercising fertilizer control, can come to an agreement respecting a uniform system of labels and of methods of expressing analysis. This subject, as is well known, has been under discussion by our association for several years, and satisfactory and encouraging progress has been made. This leads to the hope that in a few years more the representatives of each State in this association may come to an agreement on this important subject.

The committee does not deem it wise to favor any form of national legislation which would in any way interfere with the State system of control of fertilizers. That is a matter with which, in our opinion, the National Government has nothing whatever to do. The systems of control, as is well known, are not uniform. In some States a tax is laid upon the gross tonnage of fertilizers sold. In other States a tax is laid upon the labels which are attached to the various packages, and other forms of control are exercised. It is believed that the wisest control of this kind is that which seems best to the State officials who have charge of such matters, and the State legislatures which establish the legal status of such control. This committee, therefore, is opposed to any national legislation which would attempt to influence the States in any way respecting the method of control of fertilizer sales within the States.

After repeated attempts to secure suggestions from manufacturers, your committee is of the opinion that upon the whole the manufacturers themselves would rather not have national legislation and prefer to submit to the disadvantages of the present system rather than to see incorporated in a national law any system of stating analyses or the character of the materials used in the compounding of fertilizers which would be objectionable to them. This, however, does not seem a sufficient ground upon which to advise that no national action be taken, and it seems advisable to endeavor to secure from the manufacturers a full expression of their views in order that the matter may be widely discussed. If it were possible to extend the agreement among the State officials already referred to relating to methods of tag-

ging and of stating the results of analytical work, so as to obtain the approval of the manufacturers, the difficulties in the way of a national law would be practically eliminated. In this case the enactment of such a law would prove beneficial to all parties by aiding in securing the agreement among the various States.

Your committee therefore recommends that for the present no attempt be made to bring a national fertilizer law to the attention of the Congress with the object of controlling commerce in fertilizers in the District of Columbia and the Territories of the United States and in interstate commerce, but that, on the other hand, an effort be made to secure an agreement among all the State officials respecting the fundamental definitions of the misbranding and adulteration of a fertilizer, and a common understanding respecting the proper method of tagging or branding, and the proper method of stating the results of analysis; that an attempt be made to secure an agreement between the officials of the States and the fertilizer manufacturers respecting the proper method of referring to the crude sources of the plant food which may be present in any given fertilizer. This committee believes that all these points should be settled before any concerted effort is made to bring the matter of national fertilizer control to the attention of Congress. Further than this, your committee is of the opinion that when such an effort is made it should relate solely to the fundamental conditions above mentioned, and should be so conducted as not in any way to affect the States in respect to the proper methods of raising revenue from fertilizers sold under the State control.

Tentative Definitions of Fertilizers and of Misbranding and Adulteration.—(1) A fertilizer shall be defined as any simple, compound, or mixed material, prepared for the purpose of selling, or sold, or offered for sale, to be applied to the soil as nourishment for plants, or as a modifier of the soil in any respect in its relation to the growth of plants. The term "fertilizer material" (or ingredients) shall include every plant-food material which is utilized, or intended to be utilized, in the manufacture, preparation, or mixing of the fertilizers defined above.

(2) A fertilizer, or fertilizer material (or ingredient), shall be deemed to be adulterated:

(a) If the percentage of any of its ingredients fall materially below the professed standard under which it is sold, whether this standard appear as a label upon the package or as a guaranty in any other way by the vendor thereof.

(b) If any of the ingredients thereof have an origin other than that indicated upon the package, or guaranteed in any other way by the vendor thereof.

(c) If any of the ingredients of the fertilizer, or fertilizer material, be in a state of combination different from that indicated by the label or guaranteed by the vendor thereof.

(3) A fertilizer, or fertilizer material, shall be deemed as misbranded:

(a) If any false name or misleading statement or design or device be affixed to any package thereof or used in any way as a representation of the materials thereof by the vendor.

(b) If any false or misleading statement respecting the origin of the material be made upon the label, or any statement or guaranty of the vendor.

(c) If any false or misleading statement be made upon the label, or by the vendor, respecting the country or origin of the materials of which the fertilizer is composed.

(d) If any false or misleading statement be made on the label, or by the vendor, respecting the virtues or qualities of the fertilizer or the materials composing it.

(e) If sold under any false name or appellation, whether such name appear upon the package or label or be given to the article by the vendor thereof.

(f) If it be an imitation of or offered for sale under the name of another fertilizer or fertilizer material.

The Meaning of the Guarantee.—It has been said that the manufacturer, dealer, or jobber must have printed on the bags or tags attached to the bags, his name and address, the weight of the package, the name, brand or trade mark, and the chemical composition of the fertilizer. This guarantee does not mean that each particular shipment, or lot, or bag, that the consumer may purchase has been analyzed by the state chemist and that he found the stipulated amounts of nitrogen, soluble phosphoric acid, reverted phosphoric acid and potash, as the case may be, that are printed as the guaranteed chemical analysis on the bags or tags. It does mean that the manufacturer says he has furnished at least those amounts of plant food as stated.

The Interpretation of the Guarantee.—Some manufacturers do not make a simple statement of the guaranteed chemical composition of their brands of fertilizers, but use other terms which are equivalent, to be sure, but are misleading to the ordinary person not familiar with fertilizer parlance. A few examples may serve to illustrate this point.

Guaranteed Chemical Analysis No. 1.

	Per cent.
Nitrogen	1.00
Ammonia	1.22
Equal to nitrate of soda	6.06
Total phosphoric acid	12.00
Equivalent to bone phosphate	26.00
Available phosphoric acid	10.00

To simplify this guarantee we would state it as:

	Per cent.
Nitrogen as nitrate	1
Total phosphoric acid	12
Available phosphoric acid	10

All the other statements omitted in the simplified chemical guarantee are correct but unnecessary and misleading. The percentage given under "equal to nitrate of soda," and "equivalent to bone phosphate" are simply restatements.

Conversion Factors.—The following may be of help in obtaining equivalents of fertilizer ingredients:

1 per cent. nitrogen	= 1,2154	per cent. ammonia.
1 per cent. ammonia	= 0.823	per cent. nitrogen.
1 per cent. nitrogen	= 6.06	per cent. nitrate of soda.
1 per cent. nitrate of soda	= 0.165	per cent. nitrogen.
1 per cent. nitrogen	= 7.207	per cent. nitrate of potash.
1 per cent. nitrate of potash	= 0.139	per cent. nitrogen.
1 per cent. nitrogen	= 4.791	per cent. sulphate of ammonia.
1 per cent. sulphate of ammonia	= 0.209	per cent. nitrogen.
1 per cent. potash	= 1.582	per cent. muriate of potash.
1 per cent. muriate of potash	= 0.632	per cent. potash.
1 per cent. potash	= 1.849	per cent. sulphate of potash.
1 per cent. sulphate of potash	= 0.541	per cent. potash.
1 per cent. potash	= 1.467	per cent. carbonate of potash.
1 per cent. carbonate of potash	= 0.682	per cent. potash.
1 per cent. nitrate of potash	= 0.466	per cent. potash.
1 per cent. potash	= 2.146	per cent. nitrate of potash.
1 per cent. phosphoric acid	= 2.185	per cent. bone phosphate of lime.
1 per cent. bone phosphate of lime	= 0.458	per cent. phosphoric acid.

Example: Muriate of potash guaranteed 80 per cent. contains 80 × 0.632 or 50.56 per cent. potash. Nitrate of soda guaranteed 95 per cent. contains 95 × 0.165 or 15.68 per cent. nitrogen. 15.68 per cent. nitrogen is equivalent to 15.68 × 1.2154 or 19.06 per cent. ammonia.

Guaranteed Chemical Analysis No. 2.

	Per cent.
Total phosphoric acid	11-14
Equivalent to total bone phosphate	24-30
Available phosphoric acid	10-12
Equivalent to available bone phosphate	22-26
Soluble phosphoric acid	8-10
Equivalent to soluble bone phosphate	17.5-22
Insoluble phosphoric acid	1-2
Equivalent to insoluble bone phosphate	2-4.25
Potash	4-5
Equivalent of sulphate of potash	7.4-9
Total nitrogen	2-3
Equivalent to total ammonia	2.4-3.6

This is not an exaggerated guarantee but one that is often found in the fertilizer trade.

Simplified the above reads:

	Per cent.
Total phosphoric acid	11
Available phosphoric acid	10
Soluble phosphoric acid	8
Insoluble phosphoric acid	1
Potash	4
Nitrogen	2

Or we may further simplify this to read:

	Per cent.
Available phosphoric acid	10
Potash	4
Nitrogen	2

It will be noticed that the simplified statements contain the minimum percentages; for example, available phosphoric acid is guaranteed as 10 to 12 per cent. and in the simplified statement it is given as being 10 per cent. This latter figure, 10 per cent., is all the manufacturer guarantees and the maximum guarantee of 12 per cent. is misleading and does not mean anything. It seems to be common practice with the manufacturers to use both the minimum and maximum guarantees.

GUARANTEED CHEMICAL ANALYSIS NO. 3.

	Per cent.
Total phosphoric acid	10.0 to 12.0
Available phosphoric acid	9.0 to 10.0
Insoluble phosphoric acid	1.0 to 2.0
Soluble phosphoric acid	6.0 to 8.0
Equal to available bone phosphate	19.7 to 22.0
Potash	3.5 to 5.0
Nitrogen	0.82 to 1.65
Ammonia	1.0 to 2.0

Simplified this guarantee would read:

	Per cent.
Available phosphoric acid	9.0
Potash	3.5
Nitrogen	0.82

GUARANTEED CHEMICAL ANALYSIS NO. 4.

	Per cent.
Total bone phosphate	32.7 to 43.7
Yielding total phosphoric acid	15.0 to 20.0
Soluble bone phosphate	22.0 to 28.0
Yielding soluble phosphoric acid	10.0 to 13.0
Reverted bone phosphate	8.7 to 10.9
Yielding reverted phosphoric acid	4.0 to 5.0
Insoluble bone phosphate	2.2 to 4.4
Yielding insoluble phosphoric acid	1.0 to 2.0

Simplified this would read:

	Per cent.
Soluble phosphoric acid	10.0
Reverted phosphoric acid	4.0
Insoluble phosphoric acid	1.0

Or we could state it as follows:

	Per cent.
Available phosphoric acid	14.0

There are many manufacturers who put guarantees on their brands that are not misleading and may be easily interpreted by the ordinary person. A few brands from a large fertilizer factory are tabulated.

Name of brand	Guarantee			
	Total phosphoric acid Per cent.	Available phosphoric acid Per cent.	Nitrogen Per cent.	Potash Per cent.
High grade acid phosphate	17	16	—	—
Acid phosphate	15	14	—	—
Kainit	—	—	—	12
Sulphate of potash	—	—	—	50
Muriate of potash	—	—	—	50
Cotton-seed meal	—	—	6.58	—
Blood, bone and meat	10.50	9.50	1.65	1.50
Farmers' choice	10.50	9.50	1.65	1.00
Ground bone and potash	15.00	—	2.75	3.00
High grade truck grower	10.00	8.00	3.50	7.00
Ammoniated raw bone superphosphate and potash	10.50	9.50	1.65	1.50
Vegetable fertilizer	7.00	6.00	2.50	5.00
Sugar-cane grower	11.00	10.00	2.50	2.00
Raw bone rice	10.50	9.50	1.65	1.50
Special formula	8.50	7.50	4.12	—
Bone meal	18.50	—	2.50	—
Acid phosphate and potash	11.00	10.00	—	2.00

Raw Materials are Sometimes Sold on Purity.—Raw materials like nitrate of soda, raw rock phosphate and the potash salts are often sold to the manufacturers and jobbers according to the per cent. of purity as illustrated.

	Per cent.
Nitrate of soda	95
Raw rock phosphate	78
Sulphate of potash	96
Muriate of potash	80

This means that:

95 per cent. nitrate of soda contains 95 per cent. nitrates.
78 per cent. raw rock phosphate contains 78 per cent. phosphate of lime.
96 per cent. sulphate of potash contains 96 per cent. sulphate.
80 per cent. muriate of potash contains 80 per cent. muriate.

Using our conversion factors we find that the above correspond to:

15.68 per cent. nitrogen from 95 per cent. nitrate of soda.
35.72 per cent. phosphoric acid from 78 per cent. raw rock phosphate.
51.94 per cent. potash from 96 per cent. sulphate of potash.
50.56 per cent. potash from 80 per cent. muriate of potash.

CHAPTER XIII

VALUATION OF FERTILIZERS.

Interpretation of Chemical Analyses.—A chemical analysis of a fertilizer may indicate to a great extent the value or suitability of it. The following two analyses illustrate this point.

CHEMICAL ANALYSIS NO. 1.

	Per cent.
Nitrogen as nitrate	1
Nitrogen as ammonia	1
Organic nitrogen	2
Total nitrogen	4
Water soluble phosphoric acid	8
Reverted phosphoric acid	2
Insoluble phosphoric acid	2
Available phosphoric acid	10
Total potash	9
Potash as chloride	2
Potash as sulphate	7

CHEMICAL ANALYSIS NO. 2.

	Per cent.
Nitrogen as nitrate	—
Nitrogen as ammonia	—
Organic nitrogen	4
Total nitrogen	4
Water soluble phosphoric acid	2
Reverted phosphoric acid	8
Insoluble phosphoric acid	2
Available phosphoric acid	10
Total potash	9
Potash as chloride	8
Potash as sulphate	1

Both of the above fertilizers contain equal amounts of nitrogen, phosphoric acid and potash and could be stated as follows:

	Per cent.
Nitrogen	4
Available phosphoric acid	10
Potash	9

Fertilizer No. 1 contains nitrogen as nitrates and as ammonia while No. 2 does not. Both brands contain organic nitrogen; No. 1 containing 2 per cent. and No. 2 carries all of its nitro-

gen in this form. The chemist cannot always tell the source of the organic nitrogen. When the organic nitrogen is derived from dried blood, azotin, cotton-seed meal, steamed horn and hoof meal, and similar nitrogenous organic materials it is valuable but when derived from leather preparations, dissolved wool and shoddy wastes, etc., it is not so desirable. Therefore the purchaser would perhaps select Brand No. 1 for its nitrogen content as it is to be supposed that the manufacturer using high grade materials as nitrate of soda and sulphate of ammonia would furnish organic nitrogen from high grade materials.

A glance at the phosphoric acid constituents shows that both run 10 per cent. available phosphoric acid but No. 1 contains 6 per cent. more phosphoric acid in the soluble form. As soluble phosphoric acid distributes more readily in the soil than reverted phosphoric acid and is more available as plant food, we would naturally prefer Analysis No. 1 from the phosphoric acid standpoint. Glancing at the potash we find that No. 1 carries 2 per cent. as chloride and 7 per cent. as sulphate, while No. 2 shows 8 per cent. as chloride and 1 per cent. as sulphate. For crops like tobacco, potatoes, sugar beets, oranges, etc., No. 1 would be the most suitable, since these crops do better with sulphate of potash than with muriate of potash. The potash in No. 1 was in all probability derived mostly from sulphate of potash while that in No. 2 came mostly from muriate of potash.

Here is another statement that is used by some chemists in reporting analyses.

CHEMICAL ANALYSIS NO. 3.

	Per cent.
Nitrogen	3
Soluble phosphoric acid	7
Reverted phosphoric acid	3
Insoluble phosphoric acid	2
Available phosphoric acid	10
Potash	9

This statement is not so valuable as Nos. 1 and 2 because the forms of nitrogen and potash are not given. The nitrogen may all be from nitrate of soda, or sulphate of ammonia, or organic sources, or from any two or perhaps be furnished from all of

these sources. The potash may be as sulphate, or as chloride, or as carbonate, or as a mixture of any two or three of these forms in any proportion.

Here is still another statement.

CHEMICAL ANALYSIS NO. 4.

	Per cent.
Nitrogen	4
Available phosphoric acid	10
Potash	9

This analysis besides not furnishing the amounts of the forms of nitrogen and potash does not give the forms of phosphoric acid. Of this 10 per cent. available phosphoric acid all of it may be as soluble, or as reverted. It may contain both soluble and reverted phosphoric acid but in just what amounts we do not know.

The chemical analysis, when the different forms of plant food are reported, may often prove of value to those farmers who can interpret them and who understand the influence of the plant food forms on profitable crop production.

Agricultural Values.—The agricultural value of a fertilizer is represented by the crop produced. The price that is paid for a fertilizer has no bearing on its agricultural value. The agricultural value will vary with the season, the amount of fertilizer used, the nature of the soil, kind of crop, care of the crop, locality, insect damage, plant diseases, and many other conditions. It cannot be estimated and is often beyond the control of man. However, the nature of the materials that make up a fertilizer may influence its agricultural value. Market garden crops will no doubt do better with fertilizers containing plant food in available and soluble forms. For example, available phosphoric acid will give quicker returns than insoluble phosphoric acid. Nitrogen in a soluble form will be taken up more readily than nitrogen in an organic form and some organic forms of nitrogen will be more quickly available than others. In other words fertilizers that give up their plant food slowly will not have a high agricultural value for quick growing crops.

Again, the crop to be raised may have a long growing season.

If such is the case it would not pay to use fertilizer whose plant food is all in soluble forms. If the nitrogen is all soluble, as in nitrate of soda and sulphate of ammonia, it may be used up or lost before the crop has finished growing and some slower acting form of nitrogen, as is contained in dried blood, cotton-seed meal, tankage, etc., would no doubt give greater crop returns.

The value of the crop must also be considered, for crops of low market value cannot always be expected to give profitable returns with high priced fertilizers. The cost of a fertilizer of low agricultural value may be greater than one that has a high value in producing crops. Farm manures, wood ashes, land plaster, etc., may be comparatively high in price for the amount of plant food they contain or the good they do.

Commercial Values.—The commercial value of a fertilizer is entirely different from the agricultural value. It represents the retail cost of raw materials of standard quality in the market, from which the commercial or trade value of plant food may be calculated. For example, nitrate of soda may be quoted at $50 a ton. This represents its commercial value. As nitrate of soda contains 15.5 per cent. of nitrogen or 310 pounds of nitrogen in a ton, its nitrogen has a commercial or trade value of a little over 16 cents a pound. An acid phosphate containing 14 per cent. of available phosphoric acid may carry a retail price of $14 a ton, which is its commercial value. The commercial or trade value of the available phosphoric acid would be 5 cents a pound, since 14 per cent. of available phosphoric acid is equal to 280 pounds of available phosphoric acid in a ton. Or an acid phosphate may be quoted at $1 per unit. This is its commercial value. This means that the retail cost of 20 pounds of available phosphoric acid is $1. The commercial or trade value is then 5 cents a pound. The commercial or trade value does not mean that nitrogen at 16 cents a pound will produce 16 cents worth of crops, or available phosphoric acid at 5 cents a pound will produce crops that will bring 5 cents. These constituents may produce crops valued at more or less than 16

and 5 cents respectively, depending upon many conditions as season, locality, kind of crop, condition of the soil, tillage, etc. The commercial or trade value only serves as a comparison of the relative values of the different forms of plant food in the raw materials. This valuation does not represent the cost of the mixed goods. In the manufacture of fertilizers the cost of mixing, sacking, dryers, manufacturers' profit, long credits, freight, insurance, agents' profits, etc. are all added to this commercial or trade value, so that the farmer pays much more for plant food than is represented in the commercial or trade valuation. But the farmer may purchase the plant food contained in the raw materials (unmixed), for the prices as represented by the commercial or trade values, at those points where the retail prices are quoted. To get the fertilizer to his farm he will of course have to pay freight.

Trade Values.—The Experiment Stations of Connecticut, New York, Rhode Island, Massachusetts, New Jersey and Vermont make out trade values every year for those materials that are most commonly used in the manufacture of mixed fertilizers. These values are arrived at by calculating the prices of fertilizer materials for the six months preceding March 1st, and are obtained from the leading markets of southern New England and the middle northern states.

The following give the wholesale prices in New York City for fertilizer materials on January 1, 1910.

NEW YORK WHOLESALE PRICES, CURRENT JANUARY 1, 1910—FERTILIZER MATERIALS.[75]

Ammoniates.

Ammonia, sulphate, foreign, prompt, per 100 pounds..	$ 2.65	@	—
futures	2.65	@	—
sulphate, domestic, spot	2.67½	@	—
futures	2.65½	@	—
Fish scrap, dried, 11 per cent. ammonia and 14 per cent. bone phosphate, f. o. b. fish works, per unit	2.85	&	10
wet, acidulated, 6 per cent. ammonia, 3 per cent. phosphoric acid, f. o. b. fish works.	2.35	&	35

Ground fish guano, imported, 10 and 11 per cent. ammonia, and 15-17 per cent. bone phosphate, c. i. f. N. Y., Baltimore or Philadelphia	3.00	&	10
Tankage, 11 per cent. and 15 per cent., f. o. b. Chicago	2.75	@	2.80 & 10
concentrated, f. o. b. Chicago, 14-15 per cent., b. Chicago	2.75	@	—
Garbage, tankage, f. o. b. Chicago	8.00	@	—
Sheep manure, concentrated, f. o. b. Chicago, per ton	9.50	@	—
Hoofmeal, f. o. b. Chicago, per unit	2.55	@	—
Dried blood, 12-13 per cent. ammonia, f. o. b. New York	2.95	@	—
Chicago	2.90	@	—
Nitrate of soda, 95 per cent. spot., per 100 pounds	—	@	2.10
futures, 95 per cent	—	@	2.10
Phosphates.			
Acid phosphate, per unit	0.55	@	0.60
Bones, rough, hard, per ton	20.50	@	21.50
soft steamed, unground	18.50	@	21.00
ground, steamed, 1¼ per cent. ammonia and 60 per cent. bone phosphate	19.00	@	19.50
ditto, 3 and 50 per cent	22.50	@	22.50
raw, ground, 4 per cent. ammonia and 50 per cent. bone phosphate	26.00	@	27.00
South Carolina phosphate rock, undried, per 2,400 lbs. f. o. b. Ashley River	5.50	@	5.75
South Carolina phosphate rock, hot air dried, f. o. b. Ashley River	7.00	@	7.25
Florida land pebble phosphate rock, 68 per cent., f. o. b. Port Tampa, Fla.	3.75	@	4.00
Florida high grade phosphate hard rock, 77 per cent., f. o. b. Florida or Georgia ports	7.00	@	7.50
Tennessee phosphate rock, f. o. b. Mt. Pleasant, domestic, per ton, 78 @ 80 per cent.	5.00	@	5.50
75 per cent., guaranteed	4.75	@	5.00
68 @ 72 per cent	4.00	@	4.25
Potashes.			
Muriate potash, basis 80 per cent., per 100 pounds	1.90	@	—
Manure salt, 20 per cent., actual potash	14.75	@	—
double manure salt. 48 per cent	1.16½	@	—
Sulphate potash (basis 90 per cent.)	2.18½	@	—
Kainit in bulk, 2,240 pounds	8.50	@	—

To give an idea of how these trade values are obtained we may presume that the wholesale price of sulphate of ammonia

for the six months preceding March 1st averaged $56.80 per ton, or 14.2 cents a pound for the nitrogen. A certain amount, usually 20 per cent., is added to this wholesale price to cover the cost of handling, insurance, etc., which would raise the price to $68 per ton, which would be the retail or commercial value of ammonium sulphate. The nitrogen then would be represented as carrying a commercial or trade value of 17 cents a pound. The trade values on all other fertilizer materials are calculated in the same way as described for sulphate of ammonia.

TRADE VALUES OF FERTILIZER ELEMENTS FOR 1909.[76]

The average trade-values or retail costs in market, per pound, of the ordinarily occurring forms of nitrogen, phosphoric acid and potash in raw materials and chemicals, as found in New England, New York and New Jersey markets during 1908 were as follows:

	Cents per pound
Nitrogen in nitrates	16½
ammonia salts	17
Organic nitrogen in dry and fine ground fish, meat and blood, and in mixed fertilizers	19
in fine[2] bone and tankage	19
in coarse[2] bone and tankage	14
Phosphoric acid, water-soluble	4
citrate-soluble[3]	3½
of fine ground bone and tankage	3½
of coarse bone and tankage	3
of cotton-seed meal, castor pomace and ashes	3
of mixed fertilizers, if insoluble in ammonium citrate[3]	2
Potash as high-grade sulphate in forms free from muriate (or chlorides)	5
as muriate	4¼

[1] Adopted at a conference of representatives of the Maine, Massachusetts, New Jersey, Rhode Island, Vermont and Connecticut stations held in March, 1909.

[2] In this report "fine," as applied to bone and tankage, signifies smaller than 1/50 inch; and "coarse," larger than 1/50 inch.

[3] Dissolved from 2 grams of the fertilizer, previously extracted with pure water, by 100 cc. neutral solution of ammonium citrate, sp. gr. 1.09, in thirty minutes, at 65° C., with agitation once in five minutes. Commonly called "reverted" or "backgone" phosphoric acid.

The foregoing are, as nearly as can be estimated, the prices at which, during the six months preceding March last, the respective ingredients were retailed for cash, in our large markets, in those raw materials which are the regular source of supply. The valuations obtained by use of the above figures will be found to correspond fairly with the average retail prices, at the large markets, of standard raw materials.

A study of the above table is interesting. It shows that valuations are given for nitrogen as nitrate, as ammonia and as organic nitrogen. The trade values for organic nitrogen are also different depending upon the source. Soluble phosphoric acid is valued higher than reverted phosphoric acid and there is also a trade value for insoluble phosphoric acid. In some states there is no distinction made between soluble and reverted phosphoric acid in trade valuation and the insoluble phosphoric is often not considered at all in mixed fertilizers. The bone products in the foregoing table are valued on their degree of fineness; the finer bone-meals command higher market prices than those that are coarse as is shown in the trade valuations of nitrogen and phosphoric acid. The potash as sulphate carries a higher trade value than potash as chloride, but this is to be expected because sulphate of potash costs more to manufacture than muriate of potash. There are many fertilizer materials not included in the above table. Those included in the table are high class products commonly used in New England and New Jersey.

How to Calculate the Commercial Value of a Fertilizer.—Let us suppose a chemist analyzes a mixed fertilizer and finds its composition to be as follows:

CHEMICAL ANALYSIS.

	Per cent.
Nitrogen as nitrates	0.50
Nitrogen as ammonia	1.30
Nitrogen as organic	2.00
Water soluble phosphoric acid	6.00
Phosphoric acid soluble in ammonium citrate (reverted)	1.80
Phosphoric acid insoluble (in water and ammonium citrate)	1.50
Potash as sulphate	0.40
Potash as chloride	3.60

The commercial valuation of the above fertilizer would be obtained by multiplying each ingredient by 20 to change to a ton basis, and multiplying this product by the trade value of each. The sum of these values would be the total commercial value as derived from the raw products.

COMMERCIAL VALUATION.

	Lbs. per 100 or per cent.				Lbs. per ton		Trade value per lb. cents		Commercial value per ton
Nitrate nitrogen	0 50	×	20	=	10	×	16.5	=	$1.65
Ammonia nitrogen	1.30	×	20	=	26	×	17	=	4.42
Organic nitrogen	2.00	×	20	=	40	×	19	=	7.60
Soluble phosphoric acid	6.00	×	20	=	120	×	4	=	4.80
Reverted phosphoric acid	1.80	×	20	=	36	×	3.5	=	1.26
Insoluble phosphoric acid	1.50	×	20	=	30	×	2	=	0.60
Potash as sulphate	0.40	×	20	=	8	×	5	=	0.40
Potash as chloride	3.60	×	20	=	72	×	4.25	=	3.06
Total commercial value								=	$23.79

Should we wish to determine the commercial value of a bone or tankage that contains fine and coarse bone the following example may illustrate the method employed. Let us suppose that on sifting the sample (which in this case is tankage), 60 per cent. of the tankage is finer than 1/50 of an inch and is therefore fine, and the remaining 40 per cent. is coarser than 1/50 of an inch and is therefore coarse. The nitrogen and phosphoric acid in the fine and coarse tankage are found to be the same and the tankage contains 6 per cent. of nitrogen and 10 per cent. of phosphoric acid. Then:

	Lbs. per 100 per cent.		Per cent. of fineness		Per cent. or lbs. per 100	
Nitrogen	6	×	60	=	3.6	in fine tankage.
	6	×	40	=	2.4	in coarse tankage.
Phosphoric acid	10	×	60	=	6	in fine tankage.
	10	×	40	=	4	in coarse tankage.

Referring to the table of trade values we arrive at the following commercial valuation of this tankage.

	Lbs. per 100 per cent.				Lbs. per ton		Trade value per lb. cents		Commercial value per ton
Nitrogen in fine tankage....	3.6	×	20	=	72	×	19	=	$13.68
Nitrogen in coarse tankage..	2.4	×	20	=	48	×	14	=	6.72
Phosphoric acid in fine tankage....................	6	×	20	=	120	×	3.5	=	4.20
Phosphoric acid in coarse tankage................	4	×	20	=	80	×	3	=	2.40
Total commercial value .								=	$27.00

The same methods as illustrated in the foregoing examples are used for obtaining the valuations on all fertilizers.

Comments Regarding Valuations.—The Vermont Experiment Station has the following to say regarding valuations.

Year after year the meaning of the valuation system is unfolded in the station bulletins, both in connection with the schedule and as a footnote to every table of analyses. Black faced type and italics are used to emphasize this matter and to point out more particularly what these valuations are not. Yet notwithstanding this extreme care they doubtless are often misunderstood and misused. Indeed this condition is met to such an extent that the application of money valuations to fertilizers is forbidden by law in one New England state and is omitted in one or two others. The writer, however, believes that they serve a good purpose when properly used, and that it is better for the present at least to employ them than to abandon them, laying, however, all possible stress on their true meaning, repeating, reiterating, stating and then restating in another form, the more surely to accomplish the desired end.

The "valuations" simply show the retail cash value of raw unmixed plant food of good quality in Boston and New York. Thus for example we will assume that the system is applied in due course to an analysis of Smith's Sugar Cane Grower and that the nitrogen in a ton "valued" at $7.94, the phosphoric acid "valued" at $8.68 and the potash "valued" at $6.81. These statements, which are just such as are made in the tables of analyses under the headings of "Valuation of nitrogen in one ton" (and similarly for the other two ingredients), do not mean that a ton of Smith's Sugar Cane Grower is worth $7.94 +

\$8.68 + \$6.81 or \$23.43. They do not mean that \$23.43 is a proper price to pay the local agent for this brand. They do not mean that this is the agent's buying price. They do not mean that this is the probable service a ton of this brand will give the farmer expressed in terms of money. They do not mean that this sum is the commercial value of the brand; much less do they mean that it is any measure of its agricultural worth. What they do mean and all they mean is simply this; that the same amounts of the very best forms of plant food as are found in a ton of Smith's Sugar Cane Grower could have been bought at retail in an unmixed condition in Boston or New York for \$23.43. They do not mean that the plant food the manufacturer used of necessity had this commercial value during this time. It may have had a less one, but it can hardly have had a greater (except in cases of marked fluctuations during the fall and winter in the prices of the crude fertilizing materials, or unless the manufacturer deliberately elected to use a commercially expensive form of phosphoric acid). The station does not pretend dogmatically to state the commercial worth or valuation of any given fertilizer. And as for its agricultural value, its crop producing power, no man can say. Adverse weather conditions, insect depredations, blight injuries, poor tillage, the use of insufficient amounts, or a dozen other contingencies may make the best of plant food of little service.

Valuations Show Cost of Plant Food.—It will be seen by this that valuations simply show the cost of ready-made plant food. The cost of this plant food, however, is but one of the many charges which determine the retail cost of commercial fertilizers. It is the main item, but there are others. The sundry forms of plant food when ready for use in making commercial fertilizers have to be mixed, stored, reground, bagged, loaded, and freighted. Then, too, commissions to agents and dealers, the expense of selling on long credit, the item of bad debts, the interest on investments, the depreciation of the manufacturing plant, profits, etc., are also proper and fixed charges. All these cost money and must, in the end, be paid for by the consumer of mixed fertilizers. Not one of them contributes in the least to plant

growth, Commercial fertilizers are usually applied in the mixed form, but this is simply a matter of convenience. The mixing adds no virtue to them (except the mixing of sulphuric acid with raw phosphate) and as good results may be obtained by the separate application of the crude ingredients.

An illustration may serve to make these statements more clear. A farmer buys in Boston or New York 50 pounds of nitrate of soda, 350 pounds of dried blood, 1,475 pounds of acid phosphate, and 125 pounds of muriate of potash and mixes these ingredients together at home on his barn floor as thousands have done before him. He will then have a complete fertilizer analyzing much the same as the average goods sold in Vermont and not essentially different chemically from many standard brands now in the market.

The cost of the ton after mixing—if the farmer prefers to mix the ingredients himself—will be made up as follows:

(*a*) Cost of material in the market.

(*b*) Cost of transportation.

(*c*) Cost of mixing.

The first item (*a*) entering into the total cost is the only one included in the "valuation." If there is added to this one item not only the charges of transportation and mixing, but also the expenses of selling through agents and dealers, long credits, bad debts, etc., we have the factors involved in the cost of our ordinary complete fertilizers when delivered. It is clear, therefore, that the selling price must of necessity exceed the "valuation," the excess representing the manufacturer's charges for converting raw materials into finished products, for freighting and for selling them.

Since the cost of mixing and selling vary somewhat with different companies, and since freight rates to the different sections of the state are quite unlike, it is unsafe to assign any arbitrary sum to cover these charges. These can be estimated best by the consumer to fit his local conditions.

Some Object to Valuations.—There are other arguments both for and against the use of valuations. The opponents of the system say:

1. The prices of raw materials vary from time to time. Logically valuations should shift similarly.

2. They are misleading, misunderstood, misapplied and, therefore, mischievous.

3. Chemical analysis does not disclose the sources of the various forms of plant food in the mixtures and hence it is difficult, if not impracticable, to apply true commercial values.

4. The use of certain forms of plant food is encouraged while that of other forms is discouraged.

Its advocates say in rebuttal:

1. Prices of raw materials do vary; but that fact has but little bearing in this matter Comparative and not absolute values are shown by the valuation system. It is emphatically and distinctly disclaimed that any attempt is made to show the commercial valuation of a given brand.

2. The uninformed or the careless may be misled; but the system is so simple and its meaning made so clear that it ought not to be misunderstood by anyone of fair intelligence. It may be misapplied by those who are misled or who misunderstand it. Many good things may be perverted through misuse; but this is not a valid argument against them. The farmer who thinks that money values are an index of crop producing merit has no conception of the meaning or use of the system. The kinds and amounts of plant food rather than its money value determine the agricultural worth of a fertilizer.

3. A full chemical analysis of a commercial fertilizer, such as the station has printed in its bulletins for years, gives every clue needed as to source and kinds of phosphatic and potassic plant food. It shows too the proportions of soluble nitrogen. As for organic nitrogen, however, it must be said that, while chemical analysis can tell how much is present, it cannot surely tell how good it is. In other words, nitrogenous materials of an organic origin, when mixed with the other ingredients of fertilizers, lose their indentity to such an extent that it is difficult and often impossible to say what is what. Low grade materials, however, if in considerable quantities can be detected with a fair degree of assurance.

It should be noted that here again the objectors to the valuation system miss the point. The nitrogen valuations show the retail cash cost of equivalent amounts of high grade nitrogen. They do not show the retail cash cost of the nitrogen used in the brand in question which may or may not have been of good quality.

4. The valuation system does seem to favor the use of rock phosphates rather than of bone phosphates. Commercial conditions, however, have for years been such that the former has been the cheaper. A pound of soluble phosphoric acid from one is, so far as is known, of equal agricultural value to a pound of the other. The reverted phosphoric acid from each source is probably of nearly equivalent agricultural values, with the bone phosphate, perhaps, a bit the better. The insoluble phosphoric acid derived from bone phosphate is agriculturally better and commercially more costly than its competitor. The trade values for soluble and available phosphoric acids are based more on rock than on bone prices, while that for insoluble phosphoric acid is a sort of compromise. Since the available (soluble and reverted) phosphoric acid in the rock goods is almost if not quite as serviceable agriculturally as that from bone and since it is much cheaper it is generally to be preferred. This condition is reflected in the trade values for this ingredient.

Some Favor Valuations.—Those who have fathered the system say for it that, while it is open to misuse, it is particularly serviceable in two ways:

1. To show whether a given fertilizer is worth its cost from the commercial standpoint.

2. As a common basis on which to compare the commercial values of different brands, enabling buyers to note whether prices asked are warranted by values contained.

It expresses these highly variable percentages in concrete shape. Many farmers are not as well acquainted with nitrogen, phosphoric acid and potash as they should be; but they know dollars and cents. And if they realize that these dollars and cents are a purely commercial measure and not an agricultural one, the system should be of service to them.

It has been suggested that it were better to express the valuations in the analyses tables all as one figure instead of splitting them between the three ingredients. This is the common procedure in other states but it has not approved itself to us. By dividing the figures thus it emphasizes the fact that these values spring from the sundry forms of plant food. It calls attention to nitrogen, phosphoric acid and potash instead of leading one away from their consideration. It prepares the way for a better understanding of the whole matter and, indeed, it is to be hoped, for the ultimate abandonment of the valuation system.[77]

Valuations in Other States.—In some states the valuations are obtained from the ruling prices of the raw materials at the large fertilizer market or markets in the state, or nearby. Louisiana for example makes out values according to the prices quoted in New Orleans; South Carolina on prices at Charleston; Georgia on prices at Savannah, etc.

To make this clear let us examine the Georgia valuations for the season of 1908-1909.

Commercial Values of Fertilizers and Fertilizer Materials for the Season of 1908-1909, as Fixed by State Chemist, January 1, 1909.

About the first of January, 1909, quotations at Savannah on principal ingredients used in the manufacture of commercial fertilizers were as below:

Acid phosphate 13-14 per cent. at $9.00 per ton 2,000 pounds.

Phosphate rock 68 per cent. bone phosphate $5.59 per ton f. o. b. cars Savannah, Ga.

German kainit $10.00 per ton 2,000 pounds f. o. b. cars Savannah, in sacks.

Muriate of potash $39.00 per ton 2,000 pounds f. o. b. cars.

Nitrate of soda $50.00 per ton 2,000 pounds f. o. b. cars in sacks.

Cotton-seed meal $25.00 per ton 2,000 pounds f. o. b. cars.

Sulphate of ammonia $62.00 per ton 2,000 pounds f. o. b. cars.

Pyrites per unit of sulphur ex-ship Savannah $6.50 per ton for 50 per cent. ore.

Brimstone $24.00 per ton ex-ship Savannah.

Western dried blood $2.85 per unit of ammonia.

Bone tankage $2.85 per unit of ammonia.

Raw bone-meal $23.00 per ton 2,000 pounds.

Steam bone-meal $22.25 per ton 2,000 pounds.

Tennessee phosphate rock 75 per cent. bone phosphate of lime $6.45 per ton at Atlanta.

Valuations.

The above prices are quotations at wholesale figures for lots of 500 tons and over, spot cash ex-ship, cars or warehouse, Savannah, Charleston and Atlanta.

The nitrogen of bone-meal which passes through a sieve with perforations 1-50 of an inch in diameter is valued at $3.55 a unit.

The nitrogen of bone-meal coarser than that is valued at $2.30 a unit.

The phosphoric acid of bone-meal finer than 1-50 of an inch is valued at 70 cents per unit. Coarser than 1-50 inch is valued at 55 cents a unit.

Cotton-seed meals are valued as heretofore by multiplying their nitrogen percentage by the value of nitrogen ruling for the season, viz: $3.55 per unit, and adding to this result, $3.33 to cover the value of the 1.8 per cent. potash and 2.7 per cent. phosphoric acid which is the average content of these meals.

In the case of Sea Island meals $2.53 is added to cover the 1.5 per cent. potash and 1.9 per cent. phosphoric acid which is the average content of these meals.

On the basis of the above quotations the following commercial values have been calculated, and have been used in calculating the values of all the goods offered for sale in the State during the season of 1908-1909, as exhibited in the table of analyses:

Available phosphoric acid	3½ cents a pound
Nitrogen	17¾ cents a pound
Potash	4 cents a pound

It is usual, however, in the fertilizer trade, and very convenient in calculation, to use the system of units. A unit means, in technical talk, one per cent. of a ton, or twenty pounds; so

that converting the above prices per pound into prices per unit, by simply multiplying by 20, we have:

Available phosphoric acid	70 cents	a unit
Nitrogen	$3.55	a unit
Potash	80	a unit

For example, suppose we have a fertilizer with 8 per cent. available phosphoric acid, 3.45 per cent. nitrogen, and 2.75 per cent. of potash, we calculate its value thus:

8 per cent. ×	70 cents a unit =	$ 5.60
3.45 per cent. ×	$3.55 cents a unit =	12.25
2.75 per cent. ×	80 cents a unit =	2.20
		$20.05
Inspection, sacks, mixing and handling		2.60
		$22.65

Therefore, the relative commercial value of the above goods is twenty-two dollars and sixty-five cents per ton.

The above figures represent, as nearly as we can arrive at it, the wholesale cash cost of the goods at central points of distribution and production. If it is desired to learn the retail cost it would be necessary to add to the above total the freight to the particular point interested, and also storage, insurance, interest, taxes and the dealer's or manufacturer's profit. The figures I have given above can not, from the nature of the case, be exact, as prices fluctuate from day to day and month to month, but they approach with reasonable accuracy the wholesale cost of the goods.[78]

The form of nitrogen and potash, and the insoluble phosphoric acid are not considered in mixed fertilizers in the Georgia valuations. That is, nitrogen as nitrates, as ammonia and organic nitrogen are given equal value, and potash as sulphate and as chloride are rated the same in mixed fertilizers. Georgia allows $2.60 per ton for the cost of inspection, sacks, mixing and handling. Florida fixes an allowance of $1.50 per ton for mixing and bagging. Louisiana, South Carolina and Mississippi use practically the same system of valuation as Georgia.

CHAPTER XIV.

HIGH, MEDIUM AND LOW GRADE FERTILIZERS.

Fillers.—The low grade fertilizers and sometimes the medium grades carry materials that furnish only small amounts of nitrogen, phosphoric acid and potash or none at all. In order to fully understand the discussion which follows, let us find out if possible the way this extra material that does not furnish plant food happens to be in low grade and occasionally in medium grade fertilizers.

A filler is any substance in a fertilizer besides the nitrogen, phosphoric acid, or potash. In the general meaning of the term, a filler is spoken of as something added to a fertilizer to make weight.

The principal substances used for fillers are gypsum, sand, marl, pyrites cinders, powdered cinders, dried peat, etc. The following example will illustrate an instance where the manufacturer would use a filler.

Suppose a manufacturer wants to make a fertilizer guaranteed to contain 8 per cent. available phosphoric acid, 1.65 per cent. nitrogen, which is equivalent to 2 per cent. ammonia, and 2 per cent. potash. He has on hand acid phosphate containing 14 per cent. available phosphoric acid, nitrate of soda containing 15.50 per cent. nitrogen, and muriate of potash containing 50 per cent. potash. Since 8 per cent. available phosphoric acid is equal to 8 pounds of phosphoric acid to every 100 pounds of fertilizer, in 2,000 pounds he has 8×20 or (160) pounds of available phosphoric acid. In the same way he finds that he must have 33 pounds of nitrogen and 40 pounds of potash. By the following proportion the manufacturer finds the number of pounds of acid phosphate, nitrate of soda, and muriate of potash he will have to use to make 8-2-2 fertilizer:

14:100::160: number of pounds of acid phosphate required.

15 1-2:100::33:number of pounds of nitrate of soda required.

50:100::40:number of pounds of muriate of potash required. That is,

1,143 pounds of acid phosphate containing 14 per cent. available phosphoric acid.
213 pounds of nitrate of soda containing 15.5 per cent. nitrogen.
80 pounds of muriate of potash containing 50 per cent. potash.

Total...1,436 pounds.

The manufacturer must add 564 pounds of filler, in the form of cinders or whatever he has on hand, to make 2,000 pounds and meet the guarantee of 8-2-2. The manufacturer generally adds a slight excess of each of these fertilizing ingredients in making his goods, to make sure that his goods will reach the guarantee.

How to Avoid Paying the Freight on Fillers.—Now suppose the purchaser would buy this fertilizer without the addition of 564 pounds of filler, let us see the amount of plant food he would get.

1,143 × 14 = 6,1002 ÷ 1,436 = 11.14% available phosphoric acid.
213 × 15.5 = 3,301.5 ÷ 1,436 = 2.30% nitrogen.
80 × 50 = 4,000 ÷ 1,436 = 2.79% potash.

The analysis with and without the filler is:—

	With 564 lbs. filler	Without filler
	2,000 lbs.	1,436 lbs.
	Per cent.	Per cent.
Available phosphoric acid	8	11.14
Nitrogen	1.65	2.30
Potash	2	2.79

From this it is readily seen that 1,436 pounds of the higher grade fertilizer is better than 2,000 pounds of the lower grade. The purchaser would do well to buy the above fertilizer without the filler for he would receive more for his money. But the purchaser must have 8-2-2 fertilizer and so the manufacturer, to oblige him, must add some 564 pounds of worthless material to make the ton. The fertilizer is shipped and the purchaser has

got more bulk in the 2,000 pounds than in 1,436 pounds. But he pays freight and has the trouble of handling 564 pounds of useless filler. Or he pays freight on 10 (200 pound) sacks when a little over 7 of such weight packages would contain the same amount of plant food. It would indeed be a better proposition, should the fertilizer be too concentrated, to add soil to it when ready to use on the farm.

Cheap Fertilizers Often Demanded.—It is the writer's belief, from conversations with many fertilizer manufacturers, that these gentlemen would much prefer selling only high grade fertilizers. These manufacturers argue that high grade fertilizers are cheaper for the consumer to purchase and give better crop returns than low grade fertilizers; hence the use of high grade fertilizers would mean an increase in business as nobody is well pleased unless successful. Many farmers want the cheapest fertilizers they can get per ton price regardless of the plant food furnished, and many unscrupulous merchants desire the lowest price per ton fertilizers because they claim they can sell them for almost as much as high grade fertilizers bring; thus they make greater profits. The manufacturer rather than lose a customer, by showing the folly of such practice, ships the fertilizer with 100 to 1,000 pounds of worthless material as filler.

Cost of the Different Grades of Fertilizers.—The Vermont Experiment Station discusses the values of the different grades of fertilizers as follows:[79]

1. **From the Standpoint of Cost.**—The brands of fertilizers analyzed for the season of 1909 may be classified as to selling price as follows:

	Number of brands	Per cent. of total	Average selling price
Low priced, selling at $28 or below	39	30	$26.29
Medium priced, selling from $28.50 to $32.50	54	41	29.93
High priced, selling for $33 or more	38[1]	29	37.84

The average, largest and smallest values of plant food offered in the groups of brands appear below. The figures show the values of plant food bought for a dollar in the average goods of each grade, including the greatest as well as the least value obtained in any brand in each class.

VALUE OF PLANT FOOD BOUGHT FOR A DOLLAR.

	Average	Smallest	Largest
Low priced	$0.53	$0.40	$0.70
Medium priced	0.58	0.40	0.74
High priced	0.65	0.49	0.74

A highly nitrogenous and relatively costly oats and top dressing and a high priced tobacco goods are omitted from the comparison.

It is interesting to note the number of brands in each group which furnish less than 55 cents' worth of plant food[1] for a dollar, as well as the number which afforded more than 65 cents' worth for the same sum:

Low priced:	Less than 55c. worth, 22;	more than 65c. worth, 1.
Medium priced:	Less than 55c. worth, 13;	more than 65c. worth, 7.
High priced:	Less than 55c. worth, 2;	more than 65c. worth, 20.

The comparisons can be shown graphically. The relative length of the following lines show the average money value in plant food at retail seaboard prices bought for a dollar at Vermont delivery points in brands selling for $28 or less (low priced), from $28.50 to $32.50 (medium priced), and for $33 and above (high priced):

Low priced
53 cents for a dollar spent

Medium priced
58 cents for a dollar spent

High priced
65 cents for a dollar spent

The following lines show the proportion of the total number of brands in each group containing 55 cents or less worth of plant food for each dollar invested:

[1] The phrase "55 cents' worth of plant food" should be construed to mean an amount of plant food which, if bought for cash at retail at the seaboard, would have cost 55 cents in standard, unmixed, raw materials.

Low priced ______ 56%
Medium priced ______ 24%
High priced ______ 5%

The final set of lines show the proportion of the total number of brands in each group containing 65 cents or more worth of plant food for each dollar invested of the purchase price:

Low priced ______ 3%
Medium priced ______ 13%
High priced ______ 52%

If lines and figures are put into words, it will be seen that:

1. The same amounts of plant food which cost a dollar in the average low priced brands ($28 and below) might have been bought in the unmixed state at retail and at the seaboard for 53 cents; in the average medium priced goods ($28.50 to $32.50) for 58 cents; and in the average high priced goods ($33 and upwards) for 65 cents. Extremes of values were 74 and 40 cents. In more than a quarter of the brands the sums charged for manufacture, transportation, sale, etc., comprised 45 per cent. or more of the retail cost, thus leaving only 55 per cent. or even less to pay for the plant food; while in an eighth of the entire number these charges exceeded the seaboard value of the unmixed plant food.

2. In nearly three-fifths of the total number of low priced brands the charges for mixing, sale, etc., aggregate at least 45 per cent. of the selling price, while in only one in four of the number of medium priced brands and in but two out of thirty-eight of the high cost goods were the charges thus large.

3. Half of the total number of high class goods contained an equivalent of 65 cents or more worth of plant food at retail seaboard prices. But one in eight of the medium and one in forty of the low grade goods contain so high an equivalent.

These things are naturally so, inevitably so. There are good and sufficient reasons for this showing, which may be condensed in a nutshell as follows: It costs as much to mix, to store, to regrind, to bag, to ship, to freight, to sell, to collect for sales, etc., a ton carrying 1,200 pounds of genuine fertilizer and 800

pounds of mere filler (diluent) as one that contains 2,000 pounds of undiluted fertilizer ingredients. Therefore the buyer of low grade goods must pay for all this useless handling of the nearly or quite worthless filler. It is an old story, reiterated year after year, but it is one which needs to be told as long as material usage of low grade brands obtains.

2. **From the Standpoint of Value.**—Let us now turn the matter about and study it from the standpoint of *worth*. The figures and proportions naturally differ from those just presented. The brands may be classified as to valuation as follows:

	Number of brands	Per cent. of total	Average valuation
Low grade, valuing at $15.50 or less	42	32	$13.52
Medium grade, valuing at $15.51 to $22	59	45	18.22
High grade, valuing at $22.01 and upwards	29[1]	23	26.30

[1] Exclusive of three brands, a highly nitrogenous and relatively costly oats and top dressing, and a high priced tobacco goods, valuations of which are relatively very high, and a lawn dressing milled extra fine and sold on that account at an advance in price.

The composition, selling price and valuation of the average brand of each group appears below:

	Nitrogen	Available phosphoric acid	Potash	Total plant food, pounds	Average selling price	Average valuation	Selling price exceeds valuation by
Low grade	0.99	9.00	2.53	12.5	$27.10	$13.52	$13.58
Medium grade	2.34	8.55	4.30	15.2	30.00	18.22	11.78
High grade	3.19	7.52	9.06	19.8	38.93	26.30	12.63

A survey of this table indicates that:

1. The proportion of nitrogen increases in regular graduations from group to group; that of phosphoric acid drops one-half per cent. from the lower to the medium and one and one-half per cent. in the high grade goods; while the potash increases nearly two per cent. in the medium and over six and one-half per cent. in the high grade brands, as compared with the lower ones.

2. The low grade goods carry nine times as much phosphoric

acid as they do of nitrogen and nearly four times as much phosphoric acid as they do of potash. These proportions become, roughly, four and two in the medium grade. In the high grade fertilizers there are but two and one-third times as much phosphoric acid as nitrogen, and one and one-half per cent. more potash than phosphoric acid. The latter grade more closely resembles the proportions commonly present in the crops ordinarily grown than do either of the other grades.

A study of the main tables and of the data in hand further shows that nine out of ten high grade goods and three out of four medium grade brands contained either nitrate or ammonia salts (water-soluble nitrogen). Only one brand in five or nine in the entire forty-two of the low grades contained this valuable form of plant food; and five of these nine contained each less than 5 pounds to a ton and but one more than 10 pounds per ton. Moreover, the organic nitrogen availability of the low grade goods tended to run somewhat lower than that of the better classes.

3. The medium grade goods for one-ninth advance in price over the cost of the low grade brands offer an eighth more plant food and three-eighths more commercial value.

4. The high grade fertilizers for three-sevenths advance in price over the cost of the low class goods furnish four-sevenths more plant food and almost double the commercial value.

5. The higher the grade the less the margin between cost and worth, both actually and relatively. In buying the average low grade brand one paid this year $13.58 for service of one sort or another (factory and office charges, freight, selling expenses, etc.) incurred in the delivery of $13.52 worth of plant food; when medium grade goods were bought, $11.78 service charges placed $18.22 worth of plant food in the buyer's hands; and when high grade goods are bought $12.63 service charges placed $26.30 worth of plant food in the buyer's hands. Or, phrasing the matter another way.

THE COST OF PLACING A DOLLAR'S WORTH OF PLANT FOOD IN THE FARMER'S HANDS WAS:

In low grade goods.............................one dollar
In medium grade goods......... .... 65 cents
In high grade goods........................... 48 cents

It may be worth while now to scan the prices paid for a pound of nitrogen, of available phosphoric acid and of potash in the several grades. The next table shows this, including the average, lowest and highest costs as well as the retail cash cost of these ingredients in Boston or New York, or, in other words, their. "valuations."

COST OF A POUND OF PLANT FOOD IN FERTILIZERS OF VARIOUS GRADES.

	Nitrogen			Available phosphoric acid			Potash		
	Average	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest
	Cents								
Low grade.....	38.0	47.0	32.3	7.6	9.4	6.5	8.5	10.5	7.2
Medium grade.	31.3	25.6	38.9	6.3	5.1	7.8	7.0	5.7	8.7
High grade....	28.3	30.6	25.6	5.7	6.2	5 1	6 3	6.8	5.7
Retail cost, Boston or New York	19.0			3.82			4.25		

The same lesson enforced in a different way, that cheap fertilizers are the most costly. Some Vermont buyers paid 47 cents for a pound of nitrogen which they might have bought for 25½ cents laid down at their doors in mixed fertilizers. They paid under similar circumstances 9½ cents a pound instead of 5 cents for phosphoric acid and 10½ cents for potash instead of 5½ cents. They paid almost double prices because they did not give the matter attention, or, perhaps, because they did not believe in "book farming." The thoughtful buyer of high class goods, sold at not overhigh prices, bought plant food at figures not much in advance of valuations plus freight rates.

This situation can perhaps be put more clearly and forcibly as follows. It should be clearly understood, however, that the

remarks have reference solely to commercial considerations; that is to say to the buying of plant food.

The best purchase of low grade goods made on the Vermont market this year, that is to say the one wherein the buyer received the most plant food for his money, was a poorer trade than was the average buying of medium grade goods or than was the worst trade made in high grade goods.

The worst trade made in medium grade goods was almost as good a purchase as was the average trade in low grade brands.

The worst trade in high grade goods was a better trade than the average purchase made of medium grade goods and it was a better trade than was the best made in low grade brands.

It ought to be said in this connection that the same brands similarly named, in different localities, as well as the same goods variously named in one locality or, indeed, in one dealer's hands, are sometimes found to sell at very different prices, and, apparently, without good reason. A few very exorbitant charges have been noted. Moreover, purchasers often fail to exercise good judgment in their choices and pay overhigh charges owing to lack of information as to what to buy and how to buy it. That this situation is largely their own fault can justly be claimed, since the State has thrown about this trade safeguards which are lacking with almost every other class of traffic. The yearly fertilizer inspection, the publication of the results of the work, the free distribution of the bulletins, the clear and concise statements as to the brands on sale, the simplicity and directness of the few fundamental facts which are the main guides as to choice and to purchase; all these are ample justification of the statement that, speaking in general terms, he who is dissatisfied with the results attained with fertilizers has himself to thank for it. This dissatisfaction may be due to unwise choice, that is to say the purchase of a goods ill-adapted to a specific purpose; or, it may arise from the realization that one has paid an unreasonably high price in view of the grade of the goods. In either case a repetition of the experience may be avoided by the exercise of a

little care as to choice. Particularly in the matter of purchase there often appears to be but little relation between price and plant food content. Thus, for example, goods guaranteed to carry uniform available phosphoric acid contents, but the highly variable nitrogen and potash contents noted below were found selling at a uniform price at points where freight rates were not materially unlike:

Nitrogen, 33 lbs.;	potash, 40 lbs.;	nitrogen and potash, 73 lbs.
Nitrogen, 41 lbs.;	potash, 30 lbs.;	nitrogen and potash, 71 lbs.
Nitrogen, 16 lbs.;	potash, 80 lbs.;	nitrogen and potash, 96 lbs.
Nitrogen, 41 lbs.;	potash, 60 lbs.;	nitrogen and potash, 101 lbs.

Occasionally two brands of the same make with identical nitrogen and phosphoric acid guaranties but with different potash guaranties (1.5 and 3 per cents.) were found sold at a flat price. That is to say a local agent will offer a corn fertilizer at $30 and a potato phosphate at $30, each containing equal amounts of nitrogen and phosphoric acid, but the latter twice as much potash as the former. This is no sin; neither is it against the law. But what well-informed buyer would choose the corn goods in preference to the potato brand?

Identical but differently named goods were sometimes sold by one and the same agent at different prices. Again, two brands with similar nitrogen and phosphoric acid guaranties but different potash figures were sold by the same agent at different prices, the higher price being asked for the lower guarantied goods.

The non-nitrogenous brands, nine of which are licensed, being relatively cheap are quite popular and somewhat widely sold. As a class they carry costly plant food. As sold this year in this State excluding one brand they average to offer only 46 cents' worth of plant food for a dollar. The excepted brand, however, offered 70 cents' worth. When one has ample home supplies of nitrogen, non-nitrogenous goods may prove advisable purchases; but commercially they are usually expensive plant food.

3. **As Between Manufacturers.**—One company averaged to charge 48 cents for placing a dollar's worth of plant food in the

buyer's hands. Yet another asked twice as much or 96 cents for the same service. In the one case a dollar bought 67 cents' worth of plant food, in the other 51 cents' worth. For more than half of the brands offered by each of two companies was asked a dollar or more for the laying down of a dollar's worth of plant food at the buyer's depot; or stating it another way, the buyer of their low priced brands paid from $1.96 to $2.49 and received therefor a dollar's worth of plant food. His neighbors paid in some cases as low as $1.33 for a dollar's worth. Which made the wiser purchase? It is not difficult for anyone to apply this test before purchase. Thus, for example: Selling price, $30; guaranty, nitrogen 2 per cent.; soluble, reverted and insoluble phosphoric acids, 6, 3 and 1 per cent.; potash, 3 per cent.; $2 \times 20 \times 0.19 = 7.60$. $6 \times 20 \times 0.04 = 4.80$. $3 \times 20 \times 0.035 = 2.10$. $1 \times 20 \times 0.02 = 0.40$. $3 \times 20 \times 0.0425 = 2.55$. $\$7.60 + \$4.80 + \$2.10 + \$0.40 + \$2.55 = \$17.45$. $17.45 \div 30 = 58$; or $30 \div 17.45 = 1.72$. Seventy-two cents' service charge for a dollar's worth of plant food. Fifty-eight cents' worth of plant food for a dollar spent.[79]

Comparisons of Grades of Complete Fertilizers.—The Kentucky Experiment Station[80] has arranged the complete fertilizers (those containing nitrogen, phosphoric acid and potash) analyzed during the season of 1908 into several grades, the grade being determined by the value of the unmixed materials.

Grade	Value of unmixed materials	Average Guaranteed Composition			Average selling price per ton	Average selling price per pound		
		Available phosphoric acid. Per cent.	Nitrogen Per cent.	Potash Per cent.		Available phosphoric acid Cents.	Nitrogen Cents	Potash Cents
1	$14.28	7.95	0.82	1.08	$24.60	10.33	36.15	10.33
2	15.34	8.92	0.41	2.42	24.85	9.72	34.02	9.72
3	17.05	8.00	1.10	2.36	25.86	9.10	31.85	9.10
4	18.24	8.75	0.82	3.58	27.21	8.95	31.33	8.95
5	19.43	8.41	1.65	2.00	26.81	8.28	28.98	8.28
6	22.38	8.00	2.06	3.44	31.55	8.45	29.57	8.45
7	22.93	7.53	1.65	5.80	31.50	8.24	28.84	8.24
8	29.65	8.80	2.86	5.90	36.00	7.28	25.48	7.28

The prices per pound of available phosphoric acid, nitrogen and potash decrease as the percentages of these constituents increase, grade 6 being an exception. Roberts states: "The goods represented by this class are all manufactured by one combination of companies that use many of their formulas in common. This fact was not observed until it was seen that the decrease in prices in this case did not follow the increase in grade of goods." The table comprises some 245 brands of complete fertilizers which were distributed as follows:

Grade 1	44 brands
Grade 2	12 brands
Grade 3	16 brands
Grade 4	42 brands
Grade 5	55 brands
Grade 6	10 brands
Grade 7	40 brands
Grade 8	26 brands

In the lower grades there were more brands than in the higher grades. No. 5, which is a medium grade, had the largest number of brands. "Only 10.6 per cent. belong to the highest grade and 31 per cent. belong to the medium high and high grades."

"A low grade fertilizer can be sold at an exorbitant price per pound for the plant food contained, and yet be sold at a less price per ton than a high grade fertilizer which is sold at a low price per pound for the plant food contained. Yet this low price per ton catches the eye of some farmers. It would be just as sensible to go to the grocer and have him make vinegar one-half water and then pay for the mixture three-fourths the price of strong vinegar, as to buy the average low grade fertilizer. The economical thing to do is to buy the higher grade fertilizer and use less of it per acre. Consider what 850 pounds of filler or dead weight in low grade materials means in the freight bill when the fertilizer has to be hauled long distances by wagon, as is the case in some sections of the state."

No Fertilizer Contains 100 Per Cent. of Plant Food.—Many people when they examine a chemical analysis of a fertilizer wonder what makes up the balance of the fertilizer.

They receive an analysis like this:

	Per cent.
Available phosphoric acid	8.04
Nitrogen	1.70
Potash	2.04

The total of the available phosphoric acid, nitrogen and potash is 11.78 per cent. There is 88.22 per cent. unaccounted for and this latter amount is what they are curious about. They say, "What is this 88.22 per cent.?"

The manufacturer may have made this fertilizer from the following formula.

550 pounds of cotton-seed meal containing 6.2 % nitrogen
340 pounds of kainit containing 12 % potash
1,110 pounds of acid phosphate containing 14.5 % available phosphoric acid

2,000 pounds, total.

Figuring these amounts in per cent. or pounds per hundred we have:

550 ÷ 20 = 27.5 per cent. of cotton-seed meal
340 ÷ 20 = 17.0 per cent. of kainit
1,110 ÷ 20 = 55.5 per cent. of acid phosphate

100.00 per cent., total.

Another way to determine the 88.22 per cent. that is unaccounted for, is to make a complete analysis of the fertilizer. To do this would cost a good deal of money and after being done would not be valuable, as the consumer is only interested in knowing how much available phosphoric acid, nitrogen and potash the fertilizer contains. Mc Candles[81] gives a complete analysis of a fertilizer made from the same materials as illustrated in this discussion, namely, cotton-seed meal, kainit and acid phosphate.

Complete Analysis of a Commercial Fertilizer

			Per cent.
Inorganic or Mineral Matters	(a)	Mono-calcic, or superphosphate of lime	9.52
	(b)	Di-calcic, or reverted phosphate of lime	3.02
	(c)	Tri-calcic, or bone phosphate of lime	1.99
		Sulphate of lime, or gypsum, or land-plaster	24.60
	(d)	Sulphate of potash	3.19
	(d)	Muriate of potash	0.30
	(d)	Potash, or potassium oxide (K_2O)	0.56
		Soda, or sodium oxide	0.29
		Common salt, or sodium chloride	5.41
		Epsom salts, or magnesium sulphate	4.14
		Magnesia, or magnesium oxide	0.41
		Magnesium chloride	1.86
		Pyrites, or bisulphide of iron	0.40
		Peroxide of iron	0.63
		Alumina	0.64
		Fluoride of lime	0.39
		Sand, or insoluble silicious matter	5.87
		Water	9.33
Organic or Animal and Vegetable Matter	(e)	Protein	13.20
		Carbohydrates (such as starch, sugar and gum)	8.11
		Fat or oil	4.37
		Fibre	1.77
			100.00

		Per cent.
(a)	Contains water soluble phosphoric acid	5.78
(b)	Contains reverted phosphoric acid	1.58
(a) and (b)	contain available phosphoric acid	7.36
(c)	Contains insoluble phosphoric acid	0.91
	Total phosphoric acid	8.27

(d) Contains actual potash, 2.45 per cent.

(e) Contains nitrogen, 2.11 per cent.

The protein, carbohydrates, fat and fiber were furnished by the cotton-seed meal.

The analysis of this fertilizer would be reported as:

	Per cent.
Available phosphoric acid	7.36
Insoluble phosphoric acid	0.91
Nitrogen	2.11
Potash	2.45

This would make a total of 12.83 per cent. of plant food and for the remaining 87.17 per cent. consult the analysis as given.

Mc. Candless also made a complete analysis of an acid phosphate or superphosphate made from South Carolina rock:

COMPLETE ANALYSIS OF AN ACID PHOSPHATE.

	Per cent.
(*a*) Mono-calcic, or superphosphate of lime	18.13
(*b*) Di-calcic, or reverted phosphate of lime	5.75
(*c*) Tri-calcic, or bone phosphate of lime	3.80
Sulphate of lime, or gypsum, or land-plaster	46.05
Potash	0.12
Soda	0.38
Sodium chloride	0.03
Bi-sulphide of iron or pyrites	0.74
Magnesia	0.14
Peroxide of iron	1.10
Alumina	1.22
Fluoride of lime	0.75
Sand or silicious insoluble matter	9.29
Water	12.50
	100.00

	Per cent.
(*a*) Contains water soluble phosphoric acid	11.00
(*b*) Contains reverted phosphoric acid	3.00
(*a*) and (*b*) contain available phosphoric acid	14.00
(*c*) Contains insoluble phosphoric acid	1.74
Total phosphoric acid	= 15.74

The above analysis shows 15.74 per cent. of total phosphoric acid and the remaining 84.26 per cent. can be found in the analysis as given.

Our previous study of the foregoing chapters has taught us that muriate of potash contains 50 to 60 per cent. of potash, sulphate of potash 50 per cent. of potash, ammonium sulphate 20.4 per cent. of nitrogen, nitrate of soda 15.5 per cent. of nitrogen, rock phosphates about 30 to 36 per cent. of phosphoric acid, and in all our study of these chapters we did not find one fertilizing material carrying 100 per cent. of any of the constituents. The plant food in fertilizer materials, that is, the nitrogen, phosphoric acid and potash, is combined with other elements, and must necessarily be so to form compounds that may be used by man. Should nitrogen equal 100 per cent. it would be a gas

separated from all other gases and impossible to use as a fertilizer commodity. But when it is combined with soda and oxygen the compound nitrate of soda is formed which is readily transported and used. What has been said about nitrogen also applies to the elements potassium and phosphorus; so it is evident that we cannot buy or make a fertilizer containing 100 per cent. of plant food.

CHAPTER XV.

HOME MIXTURES.

Definitions.—When fertilizer materials such as tankage, dried blood, nitrate of soda, sulphate of ammonia, superphosphate, bone-meal, muriate of potash, etc., are purchased and mixed at home the process is called home mixing and the product a home mixture. When these fertilizer materials are mixed by the factory the product is called a fertilizer or a mixed fertilizer. Most of the fertilizer materials contain either one or two constituents and only a few carry all three constituents. Most of the mixed fertilizers contain three constituents, namely, nitrogen, phosphoric acid and potash and are called complete fertilizers because they contain the three essential elements. There has been a great deal of discussion as to whether fertilizer materials or mixed fertilizers are the best for the consumer to purchase.

Manufacturers' Claims.—The manufacturers claim that mixed fertilizers are the best for the farmer to purchase because:

1. The factory mixed fertilizers are in a fine mechanical condition. The mixed fertilizers are ground fine and uniformly mixed, which is indeed an important consideration to permit of an even distribution on the land.

2. The mixed fertilizers can generally be purchased in the locality at most any time and in any amount.

3. The mixed fertilizers are specially treated with acid and the constituents in substances like tankage, dry ground fish, etc., are made partially available.

4. The mixed fertilizers are claimed to be made up in such proportions as to satisfy the need of crops.

5. The manufacturers often allow the farmer some time to settle and often wait until harvest time before getting their money. The credit system is in vogue in the South where enormous quantities of mixed fertilizers are used.

Reasons Why the Farmer Should Mix Fertilizer Materials at Home.—The mixing of fertilizer materials at home is becoming more popular among the farmers. Some of the reasons why the farmer should mix his own fertilizer materials follow:

1. Plant food is obtained at a lower price.
2. The farmer knows the materials used.
3. Unnecessary constituents are not purchased.

Mechanical Condition of Factory and Home Mixed Fertilizers.—The factory mixed fertilizers are usually much better mixed than those that are mixed at home. Fertilizer factories are well equipped with special machinery to insure producing a uniform product that may easily be distributed on the farm. However, the careful farmer may mix his fertilizer materials uniformly enough for all practical purposes.

Mixed Fertilizers More Easily Purchased.—Mixed fertilizers can generally be purchased in the locality and the raw materials must be ordered away from home which of course takes some time. Sometimes certain raw materials are hard to obtain. If the farmer starts early enough, say in the winter, the raw materials can generally be obtained.

Mixed Fertilizers Compounded for the Needs of the Crop.—When a manufacturer makes up his formulas he has to allow for the general existing conditions of soil, climate, and needs of the crop, and he cannot expect to make a particular brand that will suit each farmer's requirements. When he makes up a potato brand he must make a mixture that will suit most of the farmers growing potatoes and he cannot expect to meet every condition of soil.

Manufacturers Often Allow Credit.—On the whole, the credit system is a poor system for the farmer, for when his crop is made he may or may not be ahead financially. Those that live on the credit system are usually a year behind and two or three poor crops result in the loss of the farm. The manufacturers, however, are often too lenient in selling their mixed fertilizers on the credit basis as they often have large losses which take away much of their profit.

Plant Food is Obtained at a Lower Price in Home Mixtures.—The work of the Experiment Stations has proved conclusively that plant food is obtained at a lower price when the fertilizer materials are purchased and mixed at home than when mixed fertilizers are employed. Of course in using home mixtures,

freight on fillers is saved. The following table shows the amount of plant food that was purchased for $30 in factory mixed fertilizers and home mixtures for the year 1906 in Connecticut.[82]

PLANT FOOD BOUGHT FOR $30.

	Nitrogen Pounds	Phosphoric acid Pounds	Potash Pounds	Total
Nitrogenous superphosphates				
In the best	73	188	111	372
In those of medium quality	44	180	97	321
In the least valuable	23	279	53	355
Special manures				
In the best	69	170	143	382
In those of medium quality	47	174	112	333
In the least valuable	32	174	66	272
Home mixtures				
In the average of all	77	200	168	445

The amounts of nitrogen, potash and total plant food in the home mixtures are higher than in any of the factory mixtures. The phosphoric acid is only exceeded in the least valuable of nitrogen superphosphates, but the total plant food is less in this grade by 90 pounds than in the home mixtures. This is indeed a fine showing for home mixtures, and as the figures in the table represent actual market conditions, the use of home mixtures should be thoroughly considered by every farmer who is in a position to use them.

The following table covers the inspection of fertilizers for the year 1909 in Vermont.[79]

SELLING PRICES AND VALUATIONS OF FACTORY MIXED FERTILIZERS.

	Per cent. guaranteed			Per cent. found			
	Lowest	Highest	Average	Lowest	Highest	Average	Excess of average analysis over guaranty
Nitrogen	0.8	8.5	2.01	0.98	8.95	2.23	0.22
Total phosphoric acid	5.0	16.0	9.08	6.88	16.60	10.53	1.45
Available phosphoric acid	3.9	11.0	7.53	3.65	12.18	8.32	0.79
Potash	1.0	12.0	4.36	1.02	13.19	4.70	0.34
Selling price	$22.50	$58.00	$31.43	—	—	—	—
Valuation	$ 9.45	$39.86	$17.19	$10.04	$43.31	$18.84	$1.65

Note the great differences between the selling prices, or cost to the consumer, and the valuations.

The average selling price of fertilizers for the year 1909 in Vermont was $31.43 and the average valuation was $18.84. These great differences in selling prices and valuations are easily accounted for. The valuations, you well remember, are figured on the retail cost of fertilizer materials on the open market in the unmixed state. These valuations represent what a farmer should purchase his fertilizer materials for in centers like Boston, New York, etc., and they do not represent the prices of these fertilizer materials when laid down at his place, as the freight and cost of handling are not considered. When factory mixed fertilizers are purchased the consumer must pay for the cost of assembling the raw materials, cost of mixing, insurance, long credit, bad debts, storage, freight, cost of inspection, cost of filler, cost of sacks, travelling men's expenses, dealers' profits, manufacturers' profits and any other expenses that may be incurred in the manufacture and sale of the mixed fertilizer.

When fertilizer materials are purchased that run high in any constituent the unit of plant food is usually obtained cheaper than when purchased in materials, or mixtures of materials, that run low. So when a fertilizer material like muriate of potash, which carries 50 per cent. of potash, is bought, the potash is secured at a lower price than when a mixture containing 2 to 5 per cent. of potash is selected.

Home Mixing Acquaints the Farmer with the Materials Used.—When a farmer buys a factory mixed fertilizer he does not always know just the sources of the nitrogen, phosphoric acid and potash. He may desire his potash wholly as sulphate; he may want a part of his nitrogen as nitrate and a part in the organic form from dried blood. When he buys factory mixed fertilizers he has to take the word of the agent or the manufacturer. Most manufacturers are honest men who give what is asked for but when you mix at home you know just the amount and kind of materials you are using. Again, when you mix your own fertilizer materials you deal in the subject "plant food," that is, so much nitrogen, so much available phosphoric acid and so

much potash, and you do away with your old bad habit of purchasing fertilizer for a given amount per ton regardless of its plant food value.

The table on page 313 gives a few home mixtures with the analyses, cost and valuations, that were used in Connecticut.[76]

It is readily observed that the cost per ton fairly approximates the valuations. In our previous table of factory mixtures the costs were much greater than the valuations. Note the variety of materials that were used in making up these mixtures. Note the high percentages of nitrogen and potash. These are to be sure high grade fertilizers that would probably cost $5 to $15 more if factory mixed.

Home Mixing Does Away with the Purchase of Unnecessary Constituents.—Manufacturers make many brands of fertilizers but as previously said they cannot make and one brand that will suit the requirements of every individual farmer. For example, two farmers in the same locality wish to purchase a mixed fertilizer for their corn. One of these farmers may have applied farm manure or he may have plowed under a leguminous crop, while the other farmer has not supplied his soil with any organic matter and his soil may be poor and in need of humus. The fertilizer agent or merchant in this particular locality is selling a corn fertilizer guaranteed to contain nitrogen, phosphoric acid and potash in stipulated amounts. Is it reasonable to suppose that this one brand of corn fertilizer is the best fertilizer for both soils under the above conditions? The first farmer who has supplied farm manure or plowed under a leguminous crop would be wasting money in purchasing nitrogen, unless a little in the form of nitrate, which may help to give the crop a start. The other farmer would need a fertilizer containing both nitrogen as nitrate and nitrogen in some desirable organic form to help produce a crop. Again, a farmer may be growing cotton, corn, sugarcane, etc., on a soil that is very rich in available potash. It would certainly be a waste of money for him to purchase a fertilizer containing potash.

Analyses and Valuations of Home Mixtures.

Formulas. Pounds per ton of mixtures.											Analyses								Cost (unmixed) and valuation	
Nitrate of soda	Castor pomace	Dry fish	Tankage	Ground bone	Dissolved bone-black	Acid phosphate	Muriate of potash	Double sulphate of potash	Saltpeter waste	Kainit	Nitrogen as nitrates	Nitrogen, organic	Total nitrogen	Water-soluble phosphoric acid	Citrate-soluble phosphoric acid	Citrate-soluble phosphoric acid	Total phosphoric acid	Potash	Cost per ton	Valuation per ton
—	—	—	—	—	—	—	—	—	—	—	2.85	1.72	4.57	3.44	4.41	2.06	9.91	5.77	—	$28.12
125	—	—	675	—	—	800	125	275	—	—	0.94	1.74	2.68	4.99	5.03	1.72	11.74	7.47	$22.00	25.43
500	—	—	500	—	—	400	250	—	—	350	3.73	1.19	4.92	2.88	3.51	0.90	7.29	9.05	27.65	30.16
100	—	—	750	—	—	750	200	200	—	—	0.69	2.01	2.70	4.88	5.36	2.17	12.41	7.64	22.88	25.86
90	—	—	—	392	—	908	610	—	—	—	1.12	1.60	2.72	3.36	7.21	2.15	12.72	12.78	26.45	30.13
400	—	—	—	500	—	500	—	—	600	—	3.84	0.12	3.96	3.06	6.79	0.40	10.25	8.82	26.24	28.95
200	—	—	800	200	600	—	200	—	—	—	2.04	2.62	4.66	1.09	5.14	2.71	8.94	7.59	32.00	29.04
300	—	—	800	—	600	—	300	—	—	—	2.27	2.62	4.89	0.91	4.78	2.32	8.01	8.34	34.00	29.84
236	—	—	—	688	—	688	388	—	—	—	1.73	1.12	2.85	3.63	8.22	2.82	14.67	10.59	31.20	29.83
100	—	300	600	—	—	700	300	—	—	—	0.89	2.99	3.88	4.34	5.21	1.30	10.85	8.30	27.08	29.66
—	824	706	—	—	—	—	—	470	—	—	—	4.86	4.86	0.32	2.70	0.28	3.30	5.99	29.33	26.43

When home mixing is practiced the farmer can purchase those fertilizer materials that supply the needed constituents and in the most desirable forms for the needs of his soil and crop.

How to Purchase Fertilizer Materials.—The large consumer should certainly try home mixing and find out its advantages. The small farmer may find it impracticable to purchase other than factory mixed fertilizers. However, several small consumers may often advantageously club together and purchase fertilizer materials in mixed carload lots. Many manufacturers will gladly mix fertilizer materials for the farmer when the order is large enough. Of course the farmer must know just the amounts and kinds of materials he wishes when he orders in this way.

To purchase fertilizer materials to mix at home, it is necessary to start early, say in the early winter, so that they may be mixed before the heavy spring work starts. Quotations should be secured from different parties in the nearest or nearby fertilizer markets. In most large cities bids can be secured. Be ready to pay cash because these raw materials are not usually sold on credit. Buy on the guarantee and if the constituents, nitrogen, phosphoric acid and potash fail to reach their guarantees demand a rebate. This can be easily arranged by making a contract with the manufacturer or broker.

How to Mix Fertilizer Materials at Home.—The fertilizer materials may be mixed in a wagon box, or better, on a tight barn floor, or a floor covered with canvas. Whenever chemicals as nitrate of soda, potash salts, etc., are used, they should be well broken up and rendered as fine as possible. In mixing, the light bulky materials as dried blood, cotton-seed meal, dry ground fish, etc., should be put on the bottom of the floor and on top of these spread the other materials. The materials should be spread evenly and then turned over and over and thoroughly mixed by shoveling. It takes considerable time to mix fertilizer materials so that the mixture is uniform. After the mixing is completed the fertilizers should be bagged and kept in dry storage until ready for use. If the mixture predominates in concentrated salts, some earth may be incorporated to insure a more even mixture. It should be

remembered that the chief advantage of buying factory mixed fertilizers is that they are better mixed and the farmer cannot spend too much time in the process of thoroughly mixing his fertilizer materials.

Rebates.—Every large consumer of fertilizers or those that purchase directly from the manufacturers or jobbers should enter into a contract in which it is stipulated that the material will be paid for according to its percentages of nitrogen, phosphoric acid and potash. The trade values of the different constituents will, of course, vary from time to time but the principle as illustrated here will remain the same.

The writer has figured a great many rebates for the Louisiana planters, who buy directly from the manufacturers, or jobbers, who always demand a rebate when the fertilizer fails to reach the guarantee. The method given here has met with satisfaction among the planters and the manufacturers.

Let us suppose that a farmer purchased 20 tons of fertilizer at $28 a ton, guaranteed to contain:—

	Per cent.
Available phosphoric acid	10.00
Nitrogen	1.65
Potash	2.00

The chemist finds the analysis of this shipment to be:—

	Per cent.
Available phosphoric acid	10.20
Nitrogen	1.32
Potash	2.31

From the ruling values for the season, potash is taken as 1.20, nitrogen as 3.35 and available phosphoric acid as 1.

These are the ruling trade values per unit of these ingredients in unmixed fertilizers, namely:

	Per unit
Available phosphoric acid	$1.00
Nitrogen	3.35
Potash	1.20

Then, if we multiply the percentages of available phosphoric acid, nitrogen and potash as guaranteed by their respective units we get the total units guaranteed. Example:

Available phosphoric acid	10.00×1	$= 10.00$
Nitrogen	$1.65 \times 3.35 =$	5.53
Potash..............................	$2.00 \times 1.20 =$	2.40
Total units guaranteed..............................		17.93

In a similar manner the total units as found by analysis are figured. Example:

Available phosphoric acid	10.20×1	$= 10.20$
Nitrogen	$1.32 \times 3.35 =$	4.42
Potash..............................	$2.31 \times 1.20 =$	2.77
Total units found by analysis		17.39

Then the units guaranteed are, to the units found, as the contract price paid per ton, is to the actual price that should be paid per ton. Or

$17.93 : 17.39 = 28 : y \quad 17.93\, y = 17.39 \times 28$
$17.93\, y = 486.92\, y =$ \$27.16, or the actual price that should be paid per ton.

Now \$28 (the contract price per ton) minus \$27.16 (the actual price that should be paid per ton) equals \$0.84, or the rebate per ton. There were twenty tons purchased; then, 20 × \$0.84 = \$16.80, the total rebate on twenty tons.

The rebate on cotton-seed meal is arrived at in the following manner. Example: The meal is sold at \$27.00 per ton and guaranteed to contain 6.59 per cent. of nitrogen. An examination of this meal shows 6.30 per cent. of nitrogen.

Then, 6.59 (the per cent. of nitrogen guaranteed) is to 6.30 (the per cent. of nitrogen found) as \$27 (the contract price per ton) is to (the actual price that should be paid per ton).

That is, $6.59 : 6.30 = 27 : y \; 6.59\, y = 170.10,\, y =$ \$25.81 or the actual price that should be paid per ton. Then \$27 (the contract price per ton) minus \$25.81 (the actual price that should be paid per ton) equals \$1.19, or the rebate per ton.

These figures are not the same as those adopted by the Inter-State Cotton-Seed Crushers' Association for fixing rebates, as we figure on the actual nitrogen content as guaranteed and found.

The phosphoric acid and potash contents are not considered in figuring the above rebate as the planters in purchasing cotton-seed meal for fertilizing purposes, contract only for the percent-

age of nitrogen. The phosphoric acid and potash in cotton-seed meal are less variable than the nitrogen. If the purchaser is willing to accept the excess of potash and phosphoric acid at full value the price should be arranged accordingly.

The rebate on acid phosphate is figured as follows:

An acid phosphate guaranteed 14 per cent. available phosphoric acid analyzes 13.23 per cent. available phosphoric acid. Contract price per ton, $16.00.

Then 14 (the per cent. of available phosphoric acid guaranteed) is to 13.23 (the per cent. of available phosphoric acid found) as 16 (the contract price per ton) is to the actual price that should be paid per ton. Or,

$14 : 13.23 = 16 : y \quad 14\,y = 13.23 \times 16.$

$14\,y = 211.68 \quad y =$ \$15.12, or the actual price that should be paid per ton.

Then, $16.00 (the contract price per ton) minus $15.12 (the actual price that should be paid per ton) equals $0.88, the rebate per ton.

The rebates on other fertilizers are obtained in the same way as explained in the above examples, unless some other style of contract is agreed upon by the purchaser and the manufacturer or dealer or agent.

How to Calculate Percentages from Known Amounts.—Suppose you want to find out the analysis of a mixture made up of the following:

MIXTURE

600 pounds acid phosphate analyzing 14 % available phosphoric acid
150 pounds sulphate of ammonia analyzing 20 % nitrogen
100 pounds sulphate of potash analyzing 50 % potash

850 pounds, total

To find out the number of pounds of available phosphoric acid, nitrogen and potash in the above mixture, make the following multiplication.

$6 \times 14 = 84$ pounds available phosphoric acid
$1.5 \times 20 = 30$ pounds nitrogen
$1 \times 50 = 50$ pounds potash.

To calculate the percentages of available phosphoric acid, ni-

trogen and potash, divide the amounts of the constituents by the total amount of the mixture.

Available phosphoric acid,	lbs., 84 ÷ 850 = 9.88 %	available phosphoric acid
Nitrogen,	lbs., 30 ÷ 850 = 3.53 %	nitrogen
Potash,	lbs.,,50 ÷ 850 = 5.88 %	potash

If percentages are wished when one of the materials contains two constituents, the calculations may be made as follows:

MIXTURE

200 pounds dissolved bone analyzing	{ 15 %	available phosphoric acid
	{ 2.5 %	nitrogen
100 pounds nitrate of soda analyzing	18.84 %	ammonia
50 pounds carbonate of potash analyzing	64.00 %	potash
350 pounds, total		

The dissolved bone superphosphate furnishes two constituents, available phosphoric acid and nitrogen, so we must take these into consideration in our calculations.

The nitrate of soda is given as carrying an equivalent of 18.84 per cent. of ammonia. The table of conversion factors previously given, taught us that to convert ammonia into nitrogen we must multiply by the factor 0.823.

18.84 per cent. ammonia $\times$ 0.823 = 15.5 per cent. nitrogen.

Then:

2 $\times$ 15.0 = 30.0 pounds available phosphoric acid
2 $\times$ 2.5 = 5.0 pounds nitrogen from dissolved bone superphosphate
1 $\times$ 15.5 = 15.5 pounds nitrogen from nitrate of soda
0.5 $\times$ 64.0 = 32.0 pounds potash.

The percentages in this mixture would be:

Available phosphoric acid,	lbs., 30.0 ÷ 350 = 8.57 %	avail. phosphoric acid
Nitrogen,	lbs., 20.5 ÷ 350 = 5.85 %	nitrogen
Potash,	lbs., 32 ÷ 350 = 9.14 %	potash.

How to Calculate Amounts from Known Percentages.—If 2,000 pounds of a mixture analyzing

Available phosphoric acid .... 7 per cent.,
Nitrogen .... 5 per cent., and
Potash .... 6 per cent.

is desired from

Acid phosphate analyzing 16 per cent. available phosphoric acid,
Calcium cyanamid analyzing 17 per cent. nitrogen, and
Muriate of potash analyzing 50 per cent. potash.

it may be calculated in the following way:

First find out the number of pounds of available phosphoric acid, nitrogen and potash that would be required. Since 2,000 is 20 times 100 we may multiply the percentages by 20.

20×7 (% avail. phos. acid)	= 140 lbs. avail. phos. acid	req. for 2,000 lbs.
20×5 (% nitrogen)	= 100 lbs. nitrogen	req. for 2,000 lbs.
20×6 (% potash)	= 120 lbs. potash	req. for 2,000 lbs.

To determine the number of pounds of acid phosphate, calcium cyanamid and muriate of potash needed to give the analysis desired, we may divide the pounds of available phosphoric acid, nitrogen and potash by the percentages that the materials analyzed.

Avail. phos. acid	lbs. 140 ÷ 16%	= 875 lbs. acid phosphate required
Nitrogen	lbs. 100 ÷ 17%	= 588 lbs. calcium cyanamid required
Potash	lbs. 120 ÷ 50%	= 240 lbs. muriate of potash required
Total		1,703 lbs.

We have only 1,703 pounds and not 2,000 pounds the amount desired. To make 2,000 pounds an addition of 297 pounds of some make weight material as sand, earth, gypsum, etc., is necessary.

Supposing we wished to substitute kainit, analyzing 12 per cent. of potash, for the muriate of potash in the above mixture. By calculating as explained above we find that it would require 1,000 pounds of kainit to analyze 6 per cent. of potash. This amount would make our total add up to 2,463 pounds, or 463 pounds more than we wish. This shows that kainit could not be used to supply all of the potash in a 2,000 pound mixture of the above analysis made from such materials. We could, however, supply one-third of the potash from kainit and two-thirds from muriate of potash.

Potash lbs. from kainit 40 ÷ 12% = 333 lbs. kainit
Potash lbs. from muriate 80 ÷ 50% = 160 lbs. muriate of potash

Assembling the potash salts, acid phosphate and calcium cyanamid we have:

	Pounds
Acid phosphate	875
Calcium cyanamid	588
Kainit	333
Muriate of potash	160
Total	1,956

By using kainit and muriate of potash in the above proportions only 44 pounds of filler would be necessary to add to make 2,000 pounds.

Some Home Mixtures.—The following are a few mixtures that furnish practically equal amounts of nitrogen, phosphoric acid, and potash and show the possibilities of the varieties of fertilizer materials that may be used to satisfy the same percentages of the essential elements.[81]

	Pounds		Pounds
Muriate of potash	30	Sulphate of potash	10
Acid phosphate	334	Acid phos. & potash (2% K_2O)	312
Nitrate of soda	125	Cotton-seed meal	286
Muriate of potash	20	Kainit	58
Acid phosphate	281	Acid phosphate	300
Cotton-seed meal	286	Nitrate of soda	70
		Stable manure	2,000
Cotton-seed hull ashes	45	Acid phosphate	266
Acid phosphate	261	Nitrate of soda	13
Cotton-seed meal	286	Stable manure	4,000
Wood ashes (unleached)	164	Muriate of potash	30
Acid phosphate	261	Acid phosphate	334
Cotton-seed meal	286	Dried blood	167

How to Determine the Requirements of the Soil.—There are people all over this country who seem to think a chemist can tell from analyzing a soil just the amount and kind of fertilizer that is needed for growing any crop or crops. The following explanation, from the Georgia Department of Agriculture, of the value of a soil analysis explains the chemists' position in this matter and also offers the farmer a way that he may determine the requirements of his soil.

The Way for the Farmer to Analyze His Own Soil.—If any one element in a soil essential to plant growth be lacking in an available form, then that soil can not produce a good crop, no matter how rich the soil may be in the other essential elements. You naturally exclaim, then, why not have a chemist analyze the soil, and tell the farmer what element or elements are lacking in his soil and what are abundant, so that he will know how to fertilize—whether he ought to apply acid phosphate, or kainit, or cottonseed meal, or lime, one or all, to his land, so as to get the best results, and at the same time use the wisest economy in the purchase and application of fertilizers. Yes, this is a very natural idea, and it was at one time, in the earlier days of agricultural science, thought that by means of a chemical analysis of the soil, the key had been found by means of which we could unlock the secrets of Nature, and solve all the problems of practical agriculture. It was found, however, on trial, that this idea, so beautiful in theory, did not work well in practice. It was discovered, for instance, that a soil which was producing poor crops contained one-tenth of one per cent. of phosphoric acid, or, calculating to a depth of nine inches, about three thousand pounds of phosphoric acid per acre, and yet this soil was in need of phosphoric acid, because when acid phosphate was used on it as a manure it responded with largely increased yields. Evidently the phosphoric acid in this soil, although abundant in quantity, 3,000 pounds per acre, was not in a condition available to the plant, so that it could be absorbed by the roots.

Elements Soluble in Acids not Always Available.—Still when the chemist came to treat this soil with his strong chemicals, he could dissolve the phosphates in it readily. Thus, it would happen that a chemist analyzing a soil and finding in it, say, 3,000 pounds of phosphoric acid, 5,000 pounds of potash, and 4,000 pounds of nitrogen per acre, and knowing nothing else about the soil, except the results of his analysis, would report that the soil contained ample plant food for producing good crops, and was a good soil, not in need of fertilizers, when, as a matter of fact, the soil might be so poor as hardly to "sprout peas." After

many trials and efforts to imitate the action of Nature in the laboratory, the conclusion was reached that it was not possible to tell by a chemical analysis, in the case of cultivated soils, whether the soil was a fertile one or not, or what particular element should be added to it for the production of full crops.

Analysis Shows the Ultimate Resources of the Soil.—Whilst the chemical analysis is a failure from this standpoint, still it is of value from another. For instance, if I make an analysis of your soil and tell you that it contains 3,000 pounds phosphoric acid, 2,500 pounds potash, and 4,000 pounds of nitrogen, then you would be encouraged to go ahead and make this plant food more available by judicious cultivation and treatment, such as liming, the turning under of green crops, etc., feeling assured that in the end you could bring that soil up to a point where it would yield bountifully. But if as the result of my analysis I should tell you that the soil only contained 150 pounds of phosphoric acid and 200 pounds of potash per acre, why, then, you would know that the best thing you could do with that land would be to abandon it or give it away, and not waste further time and labor on it. There is, however, a practical method by which you can analyze your soil for yourself, far better than any chemist can do it for you, and by means of which you can tell for yourself whether your soil needs lime, phosphoric acid, potash or nitrogen, one or all. That method is as follows:

Method by Which the Farmer May Analyze His Own Soil.—First, select a piece of ground as level as possible, so that rain may not wash the fertilizer from one plot into an adjoining plot. Secondly, for the purpose of the experiment, mark off ten plots, each one just one-tenth of an acre in area. If convenient make the plots long and narrow, say one hundred and thirty-six feet long by thirty-two feet wide; these dimensions would enable you to have eight long rows, four feet apart, in each plot. Any other shape of plot will answer, only be careful to lay off the plots so that they shall each contain one-tenth of an acre, or 4,356 square feet. Separate the plots from each other by paths, at least three feet wide, so that the effect of

fertilizer in one plot may not be felt in an adjoining plot. It would be well to locate these experimental plots on some of your poorest land, or that which stands most badly in need of fertilizer. When all is ready carefully number the plots from one to ten so that you may keep a record of the nature and amount of fertilizer applied on each plot. Let us suppose that you decide to plant cotton on the ten prepared plots for the purpose of finding out what fertilizer constituent is most needed by your soil when growing cotton. Plant the cotton in your usual manner, after a careful preparation of the soil of the plots, thoroughly ploughing and harrowing the plots in order. Then apply the fertilizer as follows:

No. 1.—No fertilizer.

No. 2.—143 pounds of cotton-seed meal.

No. 3.—200 pounds of 14 per cent. acid phosphate.

No. 4.—80 pounds of kainit.

No. 5.—No fertilizer.

No. 6.—200 pounds of acid phosphate and 143 pounds of cotton-seed meal

No. 7.—143 pounds of cotton-seed meal and 80 pounds of kainit.

No. 8.—200 pounds of acid phosphate and 80 pounds of kainit.

No. 9.—200 pounds of acid phosphate, 80 pounds of kainit and 143 pounds of cotton-seed meal.

No. 10.—500 pounds of air-slaked lime.

In many of our soils lime is sadly lacking, and it may be just the thing needed by the soil, in conjunction with certain other fertilizers; to discover if this be the case, after having fertilized plot No. 2, mark off a strip 2½ feet in width diagonally across the plot; that is, running from one corner to the opposite corner. Apply to this strip 50 pounds of air-slaked lime, and work it in well with the soil and other fertilizer with a rake. Do the same with each of the other plots, omitting No. 10. Then when the crop begins to grow, if lime was specially needed by the soil in any of the plots, you ought to notice a marked superiority in

the 2½ foot strip which runs diagonally across all the rows in all nine plots.

In the above fertilizers it is presumed that the acid phosphate is the kind most usually sold, containing 14 per cent. of available phosphoric acid, so that 200 pounds supplies 28 pounds of actual phosphoric acid to the plot.

The cotton-seed meal is presumed to contain 7 per cent. of nitrogen, so that 143 pounds of it supplies 10 pounds of nitrogen to the plot, and the kainit to contain 12½ per cent. of potash, so that 80 pounds yield 10 pounds of potash to the plots the kainit is applied to.

In applying the fertilizers observe the following precautions: Sow each fertilizer on the plot to which it is to be applied broadcast, using your best care and judgment to distribute the fertilizer evenly over the entire plot. In order to get an even distribution it is best to sow in such quantity that you will have to go over each plot at least twice to get all the fertilizer distributed. Take care not to sow while the wind is blowing, as it may blow some of the fertilizer on to the adjoining plots. After sowing harrow the ground, and then it will be ready for you to plant.

Plant thick enough to insure a perfect stand, and at the proper time thin out to a uniform stand. Treat all the plots exactly alike, except as to the fertilizers applied. Prepare the ground in each plot the same, plant the cotton all at the same time, and always cultivate the same and at the same time each day. Take pains to have the same number of plants in each row.

Keep a Record of the Results.—It will be well to keep a notebook, with a page for each plot, in which to record your observations.

In this book record: 1st. The kind of fertilizer applied to each plot and the amount applied, on the pages set apart for the respective plots from 1 to 10. 2d. Note down the date the cotton was planted. 3d. Note the date the cotton came up in each plot. 4th. When the cotton is about two inches high on the plot containing no fertilizer, note the height and appearance of the other plots. 5th. After you have thinned out to a uni-

form stand record the number of missing plants, if any, in each plot. Of course, use every endeavor to have the same number of plants in each plot, but in case of accident to some, be sure to put down the number missing in any plot so as to make allowances. 6th. Record any other observations of interest during the growth of the crop on the different plots such as the comparative dates of blooming, number bolls to the stalk, date of opening of the bolls, height of the stalks after maturity of the plant. 7th. Keep the seed cotton from each plot to itself, weigh it by itself, and record the weight of the seed cotton from plot number one on page number one, and so on with the others. When you have picked and weighed the last pound of cotton, then you will, I think, be easily able to decide for yourself what fertilizer or combination of fertilizers your land requires. Of course, if you have had a bad season, very dry or very wet, you will not be able to decide so well, and in that case repeat the experiment another year. In this way you can analyze your own soil, and do it better than the best chemist in the world can do it for you, because you have appealed to the soil itself, you have spoken to it in the language of Nature, and it has replied in the same mute, but eloquent tongue, demonstrating the truth of her answers before your very eyes.[83]

CHAPTER XVI.

A FEW REMARKS ABOUT FERTILIZERS.

Brand and Trade Names.—There are too many farmers who purchase fertilizers on the brand or trade name and not on the plant food these fertilizers contain. The manufacturers are well acquainted with the importance of selling their fertilizers under attractive names. Some of the manufacturers even go so far as to have their brand names copyrighted to prevent their competitors from using them. Some of the older brand or trade names are well known by all the farmers in the locality where they have been sold from year to year and many of these farmers purchase Dixie Cotton Fertilizer, Great Western Wheat Fertilizer, Home Mixture, Standard Special Tobacco Manure, Celebrated Potato Fertilizer, Royal Corn Special, etc., from year to year without ever knowing their plant food content. The name sounds good to these farmers, the fertilizer has a good strong odor, the right color, and with some farmers the proper taste. These are brand and ton farmers and not plant food farmers. These farmers will tell you that their fathers used these same fertilizers.

To show that the name is no indication of the composition and suitableness of a fertilizer for a crop, the following data is submitted. In the state of Massachusetts for the year 1909, out of 66 brands sold as potato fertilizers, 46 contained potato as the only crop name, and 20 were sold in conjunction with other crop names as potato, hop, and tobacco; potato and root crop; potato and tobacco; potato and vegetable; corn and potato; potatoes, roots and vegetables; onion and vegetable. Twelve companies put out 2 brands, 5 put out 3 brands, and 3 put out 4 brands. The nitrogen guaranteed varied from 0.80 to 3.71 per cent., the available phosphoric acid from 4 to 9 per cent., and the potash from 2 to 10 per cent. All of these potato fertilizers could not have been the best for the farmer to purchase. The manufacturers evidently cater to the trade and some of them put out 2 to 4 brands so as to be able to sell one of them to the farmer,

the brand depending upon the price the farmer is willing to pay. Many of these fertilizers were high grade but the farmer should consult the plant food guarantee and not the name in selecting fertilizer. Those that were sold for corn and potato, tobacco and potato, vegetables, root crops and potatoes, etc., either do not meet the requirements of these crops, or else the purchaser is wasting money in buying excesses of plant food.

Some manufacturers put out two or three different brands made from the same goods and guaranteed the same. Thus we will find Dixie Cotton Fertilizer and Corn King Guano on the market with the same guarantee, bagged from the same pile of goods, and sold for different crops. Sometimes two different brand names are used for the same material to be sold for one crop. For example, Golden Imperial and Special Mixture may be sacked from the same material, carry the same guarantee, and be sold for one crop. The writer has seen two agents, one a merchant and the other a farmer, selling the same fertilizer under different names in the same village. The farmer, who was the least successful in disposing of his lot, thought and I guess, still thinks that the merchant had a better brand. These fertilizers of course sold for the same price and the merchant sold three times as much as the farmer, because he was a bit more popular and had a better stand. So you see the brand name helps to sell fertilizer. The farmer should buy on the plant food content and not by the name or per ton.

The manufacturers also often sell superphosphates made from rock phosphates under the name of dissolved bone, and mixtures of superphosphates (made from rock) and potash, as dissolved bone and potash. We have learned that dissolved bone contains nitrogen and phosphoric acid and superphosphates made from rock only carry phosphoric acid. So when dissolved bone or a dissolved bone and potash are sold without any nitrogen guaranteed you can rest assured that the material was made from rock. However, the soluble phosphoric acid from rock superphosphates is just as valuable as that from dissolved bone, and

the reverted is perhaps almost equally valuable from these two phosphates.

There are a large number of brands sold in the different states. Georgia uses more fertilizer than any other state and the number of brands inspected, analyzed and placed upon the market in that state since 1874-1875 follow:[84]

For the season of 1874-5	110 brands
For the season of 1875-6	101 brands
For the season of 1876-7	125 brands
For the season of 1877-8	127 brands
For the season of 1878-9	162 brands
For the season of 1879-80	182 brands
For the season of 1880-1	226 brands
For the season of 1881-2	270 brands
For the season of 1882-3	354 brands
For the season of 1883-4	336 brands
For the season of 1884-5	369 brands
For the season of 1885-6	345 brands
For the season of 1886-7	322 brands
For the season of 1887-8	337 brands
For the season of 1888-9	355 brands
For the season of 1889-90	440 brands
For the season of 1890-1	492 brands*
For the season of 1891-2	608 brands*
For the season of 1892-3	598 brands*
For the season of 1893-4	736 brands*
For the season of 1894-5	874 brands*
For the season of 1895-6	1,062 brands*
For the season of 1896-7	1,178 brands*
For the season of 1897-8	1,300 brands*
For the season of 1898-9	779 brands
For the season of 1899-1900	699 brands
For the season of 1900-1	640 brands
For the season of 1901-2	735 brands
For the season of 1902-3	895 brands
For the season of 1903-4	1,241 brands
For the season of 1904-5	1,352 brands
For the season of 1905-6	1,917 brands
For the season of 1906-7	1,840 brands
For the season of 1907-8	1,822 brands
For the season of 1908-9	2,274 brands

The number of brands marked with a star are incorrect and

misleading, as in the season of 1897-8, 843 brands were inspected, analyzed and admitted to sale, and not 1,300.

How to purchase a Fertilizer.—Sometime before you intend to purchase your fertilizer write to your Experiment Station or State Board of Agriculture for bulletins on the crops you intend to raise and also for a fertilizer bulletin. These bulletins may be had free of charge. Study these bulletins. In the bulletins on crops you will no doubt learn the plant food requirements, that is, the amounts and kinds of plant food most suitable for the crops you are interested in. The fertilizer bulletin will no doubt acquaint you with some timely suggestions on how to purchase fertilizers and will also give you the names, guarantees, analyses, and valuations of the fertilizers sold in your state. You can in all probability select a fertilizer that will meet your requirements. If any element as nitrogen, phosphoric acid, and potash is not needed, do not waste your money by purchasing a complete fertilizer but select one that contains the constituents you need and in the form or forms you desire. You are now ready to talk business with your merchant or dealer. Find out from him if he has the particular fertilizer you wish. Perhaps he has not it in stock and he will no doubt tell you he has something just as good. If the amount and kind of plant food that you wish is present in the brand that he has, why it is just as good and if not it is'nt what you want. No doubt the factory for which he is agent puts out a fertilizer of the composition you desire; you can find this out by referring to your fertilizer bulletin. If so, you may be able to get your merchant to order it for you. If his factory hasn't got it buy from one that has. You have your fertilizer bulletin and you can easily write for your fertilizer and perhaps save the agent's profit.

Study the Guarantee.—You have learned that many of the fertilizer materials as cotton-seed meal, tankage, bone-meal, dry ground fish, etc., do not always contain the same amounts of fertilizer constituents and are quite variable in composition. Therefore do not buy any of these products just because they are so named. Consult the guarantee and find out how much

plant food is offered for a certain price. The following comparative valuation shows the necessity of purchasing cotton-seed meal on its nitrogen content.

When cotton-seed meal carrying 6.58 per cent. of nitrogen, which is equivalent to 8 per cent. of ammonia, is worth $30 a ton, the other grades assume the following values, when the nitrogen content alone is considered:

Choice 6.58 per cent. nitrogen or 8 per cent. ammonia $30 per ton.

Prime 6.17 per cent. nitrogen or 7.5 per cent. ammonia $28.13 per ton.

Good 5.76 per cent. nitrogen or 7 per cent. ammonia $26.25 per ton.

This illustration of the differences in value of cotton-seed meal holds for tankage, bone meals, dry ground fish, linseed meal, castor pomace, wood ashes and similar fertilizer materials. Nitrate of soda, sulphate of ammonia, the Stassfurt potash salts, etc., are usually standard products which do not show much variation; but even in the purchase of these high class materials one should know just the amount of plant food he is buying. Usually the higher the percentages of constituents in a fertilizer material, the cheaper is the plant food.

Fertilizers Should Reach Their Guarantees.—The manufacturers, as a whole, are endeavoring to do an honest business. In making their mixtures they aim to give a little more plant food than they guarantee, so that the fertilizer will meet the guarantee under reasonable conditions. The bulletins of the different states setting forth the results of fertilizer inspection, show that the majority of the factory mixed fertilizers exceed the guarantee. But sometimes fertilizers fail to reach the guarantee in all constituents. Factory mixed fertilizers often fall below the guarantee in one element but exceed the guarantee in other elements so that the relative value is above the guaranteed value. Of course the manufacturer should furnish the consumer with fertilizer that reaches its guarantee in all elements as the purchaser has a right to expect this. Such variation is often due to

poor mechanical mixture as the manufacturer usually puts in enough of the raw materials to exceed the guarantee in all constituents. When a shipment of fertilizer fails to meet its guarantee in one or more elements, and runs above the guarantee in one or more elements, the purchaser should give the manufacturer some consideration and settle on an equitable basis and allow the manufacturer for whatever excess that may be present in any of the elements, within reasonable limits. If the purchaser contracts for a certain amount or amounts of constituents and they fall materially below the guarantee a rebate should be demanded

Fertilizer Recipes or Patent Formulas.—In Texas, Louisiana, Mississippi and Kentucky, and in all probability in other states, certain parties have been selling recipes or formulas to the farmers. The following is a copy of one of these recipes.[85]

Farm Right. $5.00.

Wallis Complete Guide for Compounding Fertilizers.—Take Saltpeter, 2 pounds; Bluestone, 2 pounds; Soda Ash, 4 pounds; Nitrate Ammonia, 2 pounds; Potash, 4 pounds. Dissolve the whole in six gallons of water; put 100 pounds of stable manure in a pen and sprinkle it with a portion of the solution. Then take 50 pounds of unslacked ashes, 5 pounds of salt and 5 pounds of lime; sprinkle these on the manure, continuing the process until the ton is completed, and let it remain in a dry place for 30 days. Use from 200 to 400 pounds per acre and bed it on the other fertilizers.

We prefer the form thus presented, but it may be variously modified without departing from the principle of our invention, so long as the same steps are taken in the manner of preparing. For example: When prepared for corn the lime and ashes may be omitted and fifty pounds more of the salt and two pounds more of the soda ash added to the ton. Second: If a lower grade of fertilizer is desired, use less of the ingredients; if a higher grade is wanted, use more. Third: Cotton-seed makes a most desirable base for the fertilizer.

NOTE—For lime lands add salt instead of lime. Any rich soil or muck will answer instead of stable manure. When earth

is used always use lime and ashes. To use as Guano, put in sand instead of stable manure, and add fifty pounds more of lime to the ton, add six pounds more of ammonia and fifty pounds more of salt. For land that is infested with bugs and worms that destroy the young plants, put in ten pounds more of bluestone to the ton. Use 200 to 400 pounds to the acre and bed on it as other fertilizers. The compound destroys all bugs and insects.

Any person using this formula without authority will be liable to a fine and imprisonment under the United States laws, and any person using same without authority will be prosecuted to the full extent of the law.

Entered in the Patent Office, June 11, 1892.

Serial No. 436,386. WALLIS & ROACH.

The above recipe is practically worthless and anybody who pays $5.00 for such a fraud gives away his hard-earned money. The bluestone and soda ash have no fertilizing value and the amount of fertilizing material present in saltpetre, nitrate of ammonia and potash can be purchased on our market for 50 cents, or less. The stable manure and the cotton-seed meal mentioned in the above circular are of course good fertilizers, but the addition of lime and potash to these materials would act upon the nitrogen present and drive it off as ammonia.

The potash present in the above mixture would drive off the nitrogen in the nitrate of ammonia.

Prof. Newell, Texas State Entomologist, says: "Bluestone in the amount mentioned in this recipe would render conditions more favorable for the ordinary insects which are injurious to farm crops."

Some of the formulas call for the use of Paris green to destroy the insects. Copper sulphate and Paris green are very liable to injure the bacteria present in farm manure and in the soil, and thus the young plants would be deprived of nourishment, to a certain extent, when such insecticides and fungicides are used.

Any farmer following the unscientific directions as laid down in this circular is bound to be disappointed with the results ob-

tained. The Experiment Stations and State Boards of Agriculture are always glad to help anybody in fertilizer problems, *free of charge,* and it is an injustice to the honest fertilizer manufacturers to waste time and money with fertilizer recipes and patent formulas.

Fertilizers do not Deteriorate Much on Standing.—The mixed fertilizers and the raw materials do not change much when kept in dry storage. The mixed fertilizers are usually compounded from materials that do not attack and set free the nitrogen present. The soluble phosphoric acid may revert and change to insoluble phosphoric but not to any appreciable extent. Therefore should a farmer have some fertilizer left over from a past season he may rest assured that it is still valuable provided it has been kept in a dry place. If fertilizer gets wet from rain or becomes very moist from any cause, there may be considerable losses of plant food.

The following table shows the effect on the soluble and insoluble phosphoric acid of fertilizers from 9 manufacturers, when kept in dry storage for the period mentioned.[86]

PHOSPHORIC ACID OF FERTILIZERS IN 1905 & 1907.

Laboratory No.		Water-soluble phosphoric acid		Insoluble phosphoric acid	
		1905	1907	1905	1907
66	Capital bone and potash compound...	1.47	1.09	2.25	2.56
77	Vegetable Special...................	6.40	6.35	0.32	0.99
51	Blood, bone and potash...............	6.60	6.05	1.27	1.22
45	Caddo cotton	5.90	5.94	0.52	0.52
17	Meridian home mixture..............	8.20	7.22	1.24	0.99
116	Texas pride soluble guano...........	6.07	6.45	0.28	0.37
79	African cotton grower...............	7.07	6.81	0.33	0.82
73	Primo H. G. raw bone spuerphosphate.	7.47	7.11	0.17	0.50
62	Scott's gossipium phospho special.....	6.27	6.22	1.44	1.51
50	Vegetable grower....................	5.65	5.69	1.02	0.75
37	Dissolved bone and potash...........	8.15	6.87	0.52	0.61
33	Acid phosphate......................	11.54	10.16	1.87	1.34
	Average	6.73	6.33	0.94	1.02
	Maximum difference...............+	1.38	..	..	+.67
	Minimum difference...............—	0.37	..	..	—.53

Samples represent nine manufacturers, mostly mixed goods.

Incompatibles in Fertilizer Mixtures.—It should be understood that fertilizer materials cannot be mixed indiscriminately. Certain fertilizer materials, when mixed, set up reactions which cause losses of plant food or change the plant food to a form or forms which are less available. When lime, or basic slag, or lime nitrate, are mixed with farm manure, guano, sulphate of ammonia, etc., or mixtures containing any of these materials, the nitrogen is set free and escapes. When lime is mixed with acid phosphate or superphosphate, the soluble phosphoric acid is changed to reverted phosphoric acid. Below are a few analyses of factory mixed fertilizers to which lime has been added.

Analyses of Fertilizers with Lime Added.

Soluble phosphoric acid	Reverted phosphoric acid	Insoluble phosphoric acid	Total phosphoric acid	Available phos. acid	Potash
1.57	8.57	1.27	11.41	10.14	4.20
1.36	8.49	1.39	11.24	9.85	3.28
0.63	8.87	0.95	10.45	9.50	2.45
4.12	6.40	0.84	11.36	10.52	3.82

These fertilizers were distributed at the rate of 75 to 100 pounds per acre. To distribute such a small quantity per acre, requires a small outlet on the fertilizer distributor which would clog when ordinary fertilizers are used, so that the manufacturers in order to sell to this trade are forced to add lime to keep these special fertilizers dry and in a fine mechanical condition. Note the high percentages of reverted phosphoric acid and the correspondingly low percentages of soluble phosphoric acid in these fertilizers.

Hall says: "Superphosphates cannot long remain mixed with nitrate of soda without setting free a certain amount of nitric acid, which is both wasteful and injurious to anyone handling the mixture. It is, however, safe enough to make up the mixture and sow it straight away; the nitric acid only begins to be in evidence when the mixture is left in a heap or in bags over night, or when it is sown from a machine which has some moving

part working in the fertilizer. Most mixtures containing superphosphate will turn into a paste round machine parts working in this material. Kainit and superphosphate will also begin to set free hydrochloric acid if they are left long together."[9]

Mixtures of certain materials tend to form products that cake or become hard, thus making them difficult to distribute evenly. A mixture of basic slag with any of the Stassfurt potash salts forms a hard cake.

The following diagram may be of interest.[87]

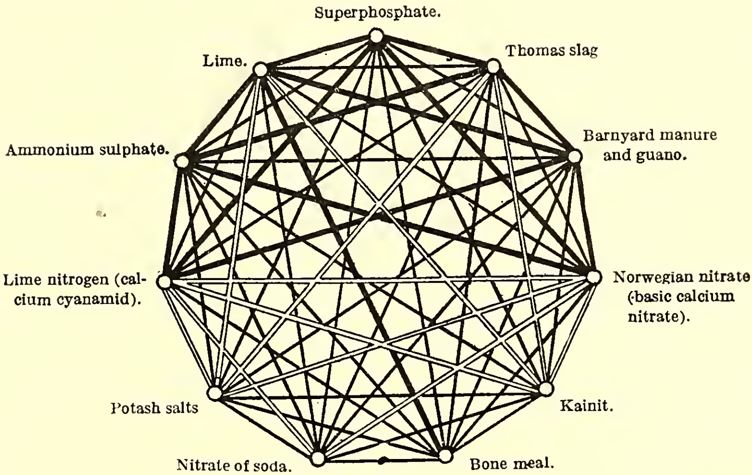

Fig. 23.

The heavy lines unite materials which should never be mixed. The double lines those which should be applied immediately after mixing. The single lines those which may be mixed at any time.

In regard to nitrate of soda and superphosphate read what Hall says in the foregoing.

The Time to Apply Fertilizer.—Nitrate of soda, sulphate of ammonia, and calcium nitrate are soluble in water and are not fixed in the soil. They should be applied in small quantities and at the proper time, or when nitrogen is needed, to give the best results. When large applications of these materials are made, some of the nitrogen may be lost by leaching. These fertilizer materials should never be worked into the soil too deeply as they

may be lost by leaching before the plant can appropriate them. The organic materials furnishing nitrogen all have to be oxidized and converted into nitrates before they may readily be acquired as plant food. These materials may be applied early enough so that they may be acted upon by the soil organisms and partially decomposed to furnish food for the young plant. The very slowly available organic substances will of course be decomposed more slowly than dried blood, cotton-seed meal, tankage, steamed horn and hoof meal, castor pomace and similar substances. One of the functions of nitrogen is to produce growth. It would be wasteful to apply any nitrogenous substance to hasten maturity. It seems almost unnecessary to make this statement but some farmers use nitrate of soda late in the season to help fill out ears of corn after the crop has been made. If nitrate of soda is added in the middle of the growing period before the ears are formed it will help to produce more vigorous growth. Generally speaking, the nitrogenous fertilizers may be applied in the spring at planting time and during the growing period when needed.

Phosphoric acid is readily fixed in the soil. When soluble phosphoric acid is added from superphosphates, it becomes well distributed in the soil, because of its fine mechanical condition, and changes to insoluble forms which are not apt to be lost by leaching. Superphosphates are very beneficial to young crops and tend to produce strong plants that can better resist the attacks of fungi and insects. Superphosphates may be applied before or during planting time. Raw bone-meal and ground rock phosphate may be applied at most any time because they are slowly available; but other fertilizers carrying phosphoric acid in the available form should be applied just before, or at planting time.

Potash is very quickly fixed in the soil by the double silicates, so that it is difficult to distribute it evenly. Potash may be applied sometime before planting so that the plowing and harrowing may help to mix it with the soil and insure a uniform distribution.

In mixed fertilizers we have found that any combination of

fertilizer materials may enter into their composition. There may be nitrate of soda, organic materials, superphosphates, and potash salts present in these fertilizers and so in the application of them we must consider the properties of all the fertilizer materials. It is generally best to apply these fertilizers in the spring. Sometimes an additional application during the growing period will help to force the crop. When much fertilizer is to be applied, especially on sandy soils, part of it may be applied in the spring and part later on when the crop may be backward or need forcing.

Crops like wheat which are sown in the fall need fertilizer at that time and also a light dressing of some nitrogenous fertilizer in the spring to help it recover from the winter. Some of the market garden crops require fertilizer at planting time and at short intervals during the growing period.

How Fertilizers are Applied.—Fertilizers are usually applied broadcast, partly broadcast and partly in the drill or hill, and in the drill or hill. When heavy applications are applied, broadcasting is perhaps the best method. The fertilizer may be applied after the last plowing and harrowed into the top part of the surface soil with a wheel harrow or some kind of a cultivator. In this way the fertilizer will become well mixed with the soil. If a broadcast distributor is not used, one-half of the fertilizer may be applied by walking north and south and the other half by walking east and west. In this way the fertilizer should be uniformly applied. When home mixtures containing farm manure or fertilizers mixed with manure are used, the manure spreader may be employed to distribute the fertilizer.

Some farmers apply fertilizer partly by broadcasting and partly in the drill or hill. This is an excellent practice for some crops and on some soils. That which is applied in the drill or hill furnishes plant food during the first growth before the roots are developed and that which is sown broadcast helps the later growth when the roots spread out. In this system of applying fertilizers it is perhaps better to apply most of the fertilizer broadcast. When farm manure is used it may all be spread broadcast and the fertilizer used to supplement it, which

is no doubt quick acting, put in the drill or hill. Potatoes, corn and market garden crops are often fertilized in this way.

With small grain, roots and other crops with small root systems, fertilizers are often applied wholly in the drill or hill. Great care should be taken in applying fertilizer in this way to keep the fertilizer away from the seed. Most fertilizers contain some nitrate of soda, potash salts, or other materials that will injure the seed if they come in contact with it. Therefore a little earth should separate the seed from the fertilizer. The fertilizer distributors usually cover the fertilizer sufficiently to protect the seed. When fertilizer is applied in the hills it should be spread over the place where the hill is to be and not applied all in one place. Earth should be spread over it as in drill application.

When fertilizer is to be applied during the growing season it may be distributed on both sides of the plants to the center of the row and worked in with a cultivator. On many hoed crops this method is used; it is also advisable on light soils that are subject to leaching. On these soils sufficient fertilizer may be applied at planting time to give the crop a start and the remainder during those periods in the growing season when the crop needs nourishment or wishes to be forced for an early market.

When fertilizers are applied to trees and bushes they should be distributed in a circle around the tree; the radius of which is equal to the height of the tree or bush. They should be worked into the soil by shallow cultivation. The feeding roots of many trees are near the surface and extend to quite a distance from the base of the tree so that by applying the fertilizer for some distance from the tree, the roots are better able to assimilate it and the soil organisms which render it available can act upon it more readily.

Is it Profitable to Use Fertilizers?—Every farmer should be able to decide this question for himself. The nature of the crop and the condition and fertility of the soil will determine whether fertilizers should be used. If intensive farming is practiced and large crops are grown on small areas fertilizers are generally required. Market garden and truck crops generally more than pay for the liberal use of fertilizer. When market garden and

truck crops are grown on high priced land large applications of fertilizer are necessary to produce maximum crops to insure profitable returns on the investment. In some sections potatoes, onions, tobacco, oranges, and other crops receiving large amounts of fertilizer give profitable returns.

If the soil is kept in good physical condition the use of fertilizers is more profitable than on soils not properly cared for. On poor soils the use of fertilizers is necessary for crop production, for without them a profitable crop cannot be produced. On farms where a systematic rotation is practiced, and farm manures and green manures are employed, the use of fertilizer to supplement the deficiencies of the soil is usually very profitable, while on farms where one crop farming is continued, the response to fertilizers is not so satisfactory. The farmer can keep his soil in good condition and profit by the use of fertilizers. Fertilizers should not always be blamed for unprofitable returns as the trouble generally rests with the farmer who is careless in his methods. Farmers should spend a great deal of time tilling the soil and not expect the fertilizer to do all the work.

Sometimes fertilizers do not prove profitable because the soil is acid or too alkaline. If these conditions are corrected the use of fertilizers is often profitable.

It should be remembered that some fertilizers like raw bonemeal, ground rock phosphate, etc., do not give up all of their plant food during the first season but may help the crops for two or three years and prove profitable in this way.

Amount of Fertilizer to Use.—Enough fertilizer should be used to produce profitable crops. This amount depends upon a great many factors, as the system of farming, the nature of the soil, the crop to be raised, and its value, the fertility of the soil, the value of the land, etc. Frequent light applications are usually more profitable than occasional heavy applications. Market garden and truck crops require more fertilizer than the staple crops. From 500 to 2,500 pounds of fertilizer are used for market garden, truck, and special crops, and 300 to 700 pounds for the staple crops, unless previous experience has shown that more or less than these amounts are necessary and profitable.

CHAPTER XVII.

FERTILIZER FORMULAS FOR CROPS.

It may be said that it is almost impossible to state just the amounts of nitrogen, phosphoric acid and potash to apply to crops. There are so many factors which enter into the needs of crops that one can only generalize.

The formulas which follow were taken from various sources and may be used as guides and not accepted as absolutely correct for all conditions. Voorhees' Fertilizers; Sempers' Manures; Snyder's Soils and Fertilizers; Card's Bush Fruits; Maynard's Successful Fruit Culture; Florida Department of Agriculture Bulletins; Georgia Department of Agriculture Bulletins; United States Department of Agriculture Farmers' Bulletins; and various Experiment Station Bulletins were used in collecting the formulas used in the following pages.

1. Staple and Special Crops.

Small Grains.—The crops that are included in this group are shallow feeders and do not utilize all the fertilizer that is necessary to apply for good substantial yields. When wheat, oats, rye, barley, or buckwheat follow some other crop as corn, an application of quickly available nitrogen and phosphoric acid is essential. Potash will also be required on light soils or following crops that use up this constituent. Top dressings of nitrate of soda in the spring help these crops to get a good start after severe winters, but nitrogen should not be added when the crop is nearing maturity as the weight of straw should be lessened to insure a good yield of grain.

Wheat is a weaker feeding crop than barley and is a harder crop to grow as it requires the soil to be in better condition. Wheat does well when it follows oats which in turn follows heavy clover sod. It may follow corn which has been well fertilized with farm manure.

Barley has a stronger root system than wheat and can thrive on soils that are not in such fertile condition as good wheat

soils. Because of its different feeding habits it may often follow wheat to good advantage. It does well on open light soils.

Oats is an easier crop to grow than wheat or barley and is more capable of gathering food than either of these crops. Oats will grow on most any type of soil that is in good physical condition.

Rye is somewhat similar to barley and is better able to acquire plant food than wheat. It is also easier to grow.

Formulas for Wheat.

Nitrogen 4 to 5 per cent. from	Nitrate of soda, or Sulphate of ammonia Dried blood	300-600 lbs. per acre.
Avail. phos. acid 6 to 8 per cent. from	D. B. black, or Basic slag, or Acid phosphate	
Potash 3 to 4 per cent. from	Muriate of potash.	

Acid phosphate, 300 lbs Sulphate of ammonia, 130 lbs Muriate of potash, 90 lbs	per acre.

This last formula is to supplement farm manure and should be applied in the fall. In the spring a top dressing of 90 pounds of nitrate of soda should be distributed.

The following formulas for wheat should receive 75 to 100 pounds of nitrate of soda in the spring in those formulas where nitrate of soda is not included. Applications of 500 pounds to the acre are recommended.

Muriate of potash	30 lbs.	Muriate of potash	20 lbs.
Acid phosphate	167 lbs.	Acid phosphate	140 lbs.
Nitrate of soda	125 lbs.	Cotton-seed meal	286 lbs.
Cotton hull ashes (20 per cent. K_2O)	45 lbs.	Unleached wood ashes	164 lbs.
Acid phosphate	130 lbs.	Acid phosphate	130 lbs.
Cotton-seed meal	286 lbs.	Cotton-seed meal	286 lbs.
Kainit	64 lbs.	Acid phosphate	133 lbs.
Acid phosphate	137 lbs.	Nitrate of soda	13 lbs.
Cotton-seed meal	143 lbs.	Stable manure	2 tons.
Cotton-seed	13⅓ bush.		
Muriate of potash	30 lbs.	Muriate of potash	15 lbs.
Acid phosphate	167 lbs.	Acid phosphate (with 2 per cent. potash)	120 lbs.
Dried blood	167 lbs.	Cotton-seed meal	286 lbs.

Kainit	58 lbs.	Muriate of potash	20 lbs.
Acid phosphate	150 lbs.	Acid phosphate	150 lbs.
Nitrate of soda	70 lbs.	Nitrate of soda	64 lbs.
Stable manure	1 ton.	Cotton-seed	13⅓ bush.

		Commercial Fertilizer to analyze as follows:	
Kainit	45 lbs.	Avail. phos. acid	4½ to 5 per cent.
Acid phosphate	132 lbs.	Ammonia	4.85 per cent.
Cotton-seed	26⅔ bush.	Potash	3 per cent.

FORMULA FOR BARLEY—250 TO 600 POUNDS PER ACRE.

Nitrogen 5-6 per cent. from	Nitrate of soda or Sulphate of ammonia
Available phosphoric acid 7-8 per cent. from	Dissolved bone-black, or acid phosphate
Potash 3-5 per cent. from	Wood ashes, or Muriate of potash

FORMULA FOR RYE—300 TO 600 POUNDS PER ACRE.

Nitrogen 4-5 per cent. from	Nitrate of soda
Available phosphoric acid 5-7 per cent. from	Acid phosphate, or Basic slag, or Dissolved bone-black
Potash 8-10 per cent. from	Wood ashes, or Muriate of potash

FORMULA FOR OATS—300 TO 600 POUNDS PER ACRE.

Nitrogen 4-5 per cent. from	Nitrate of soda, or Dissolved bone
Available phosphoric acid 5-6 per cent. from	Acid phosphate, or Basic slag
Potash 8-10 per cent. from	Wood ashes, or Muriate of potash

FOR OATS FOLLOWING CORN—200 POUNDS PER ACRE.

50 lbs. Nitrate of soda 150 lbs. Acid phosphate	add potash on light sandy soils

Buckwheat is a heavy feeding crop. It is often grown on new lands. It doesn't do well on soils rich in nitrogenous matter as the straw grows too vigorously and the grain does not fill out. It is often grown on poor soils and should be well fertilized. As it matures in early summer it should be furnished nitrogen in quickly available forms in the early spring so as to establish good growth and not interfere with seed formation.

FORMULA FOR BUCKWHEAT—400 TO 800 POUNDS PER ACRE.

Nitrogen 4-4.5 per cent from	Nitrate of soda
Available phosphoric acid 7-8 per cent. from	Acid phosphate, or Basic slag
Potash 9-10 per cent. from	Muriate of potash

Rice.—Fertilizers are not used extensively in Louisiana and Texas for this crop and the influence of the different forms of fertilizer constituents has not been determined. Phosphoric acid generally increases the yield of rice in Louisiana and Texas and potash is thought to harden the grain and improve its milling quality. Nitrogen is not necessary only on old lands and then in small amounts. If too much nitrogen is applied the plants will lodge. If organic nitrogen is employed it should be applied a long time before the crop is planted as the soil organisms that produce nitrification are retarded in activity when irrigation is practiced.

The following formula is employed by many planters.

200 lbs. Acid phosphate }
50-100 lbs. Kainit } per acre

On old lands 50 pounds of cotton-seed meal are added.

FORMULA FOR IRRIGATED RICE—500 TO 600 POUNDS PER ACRE.

Nitrogen 2-3 per cent. from	Ground bone
Phosphoric acid 8-10 per cent. from	Thomas slag, or Ground bone
Potash 3-4 per cent. from	Muriate of potash, or Kainit

If ground bone is used as a source of nitrogen it will have to be applied a long time before the crop is planted to be of any benefit. In Louisiana more quickly available forms of phosphoric acid are preferred than in this formula.

FORMULA FOR UNIRRIGATED RICE (CALLED MOUNTAIN RICE OR HIGHLAND RICE) —600 TO 700 POUNDS PER ACRE.

Nitrogen 2-3 per cent. from	Nitrate of soda
Available phosphoric acid 6-7 per cent. from	Superphosphates, or Basic slag
Potash 6-8 per cent. from	Muriate of potash, or Kainit

Staple and Special Crops.

Corn is a gross feeder and requires help in securing phosphoric acid. It is a crop that does well on large applications of farm manure, and after leguminous green manures. As this crop is a heavy feeder all the essential elements are needed. Potash helps to produce a firm stalk, nitrogen helps in vigorous growth and phosphoric acid is used in forming grain. When farm manure or leguminous green manure are supplied liberally, only a little nitrogen in a quickly available form is necessary for early growth. Potash and phosphoric acid, however, must be abundantly supplied. Like other crops the fertility of the soil and other factors influence the amount and kind of fertilizer to use.

FORMULAS FOR CORN—500 TO 1,000 POUNDS PER ACRE.

Nitrogen 2-3 per cent. from	Nitrate of soda, or Organic nitrogen
Available phosphoric acid 7-8 per cent. from	Acid phosphate, or Dissolved bone-meal
Potash 6-7 per cent. from	Wood ashes, or Muriate of potash

2 parts cotton-seed meal 1 part acid phosphate	400 lbs. per acre

This last formula is for soils rich in potash as in Louisiana. If corn follows cowpeas the nitrogen may be eliminated and 300 pounds of acid phosphate applied per acre.

1,200 lbs.	13%	Acid phosphate	400 lbs. per acre
600 lbs.		Cotton-seed meal	
200 lbs.		Muriate of potash	
2,000 lbs. total			

1,000 lbs.	Acid phosphate	230 to 450 lbs. per acre
30 lbs.	Muriate of potash	
1,250 lbs.	Cotton-seed meal	
2,280 lbs. total		

200 lbs.	Cotton-seed meal	per acre
100 lbs.	Dried blood	
200 lbs.	Superphosphate	
100 lbs.	Muriate of potash	
600 lbs. total		

Cotton is not considered an exhaustive crop but as it is often grown continuously on the same land it gradually depletes the soil of fertility. Most of the essential elements are lost to the

soil when the seed are sold away from the farm. Phosphoric acid is the important element for this crop. Nitrogen is usually supplied from high grade organic materials and when nitrate of soda is employed it should be applied at the time when it is needed. Potash seems to prevent the shedding of leaves prematurely. On soils that produce a large stalk or where cowpeas or other legumes have been turned under, no nitrogen is necessary. Some soils are rich enough in available potash to eliminate the addition of it in fertilization. Phosphoric acid in an available form seems to be always necessary.

Formulas for Cotton.

150—200 pounds cotton-seed meal 150—200 pounds acid phosphate	per acre.

This formula is suitable for Louisiana and other parts of the South where the soil is rich in available potash.

For sections where the Boll Weevil is present it is desirable to produce an early matured crop. Therefore the crop must be forced, and 50 pounds of nitrate of soda should be applied when the plants start growth.

Nitrogen 2-3 per cent. from	Cotton-seed meal Nitrate of soda	300–400 pounds per acre
Avail. phos. acid 7-9 per cent. from	Acid phosphate, or Dissolved bone-meal	
Potash 4-5 per cent. from	Cotton-seed hull ashes, Wood ashes, or Kainit.	

Georgia Experiment Station Cotton Formulas—350 to 880 Pounds Per Acre.

	Pounds
Acid phosphate	1,000
Cotton-seed meal	700
Muriate of potash	75

Barnyard manure	750 pounds	400 to 800 lbs. per acre.
Cotton-seed	750 pounds	
Acid phosphate	367 pounds	
Kainit	133 pounds	
Total	2,000	

GEORGIA COTTON FORMULAS ON WORN SOILS.

Muriate of potash	30 lbs.	Muriate of potash	30 lbs.
Acid phosphate	334 lbs.	Acid phosphate	334 lbs.
Nitrate of soda	125 lbs,	Dried blood	167 lbs.
Muriate of potash	20 lbs.	Muriate of potash	10 lbs.
Acid phosphate	281 lbs.	Acid phosphate with potash 2 per cent. (K_2O)	312 lbs.
Cotton-seed meal	286 lbs.	Cotton-seed meal	286 lbs.
Cotton-seed hull ashes	45 lbs.	Kainit	58 lbs.
Acid phosphate	261 lbs.	Acid phosphate	300 lbs.
Cotton-seed meal	286 lbs.	Nitrate of soda	70 lbs.
		Stable manure	2,000 lbs.
Wood ashes (unleached)	164 lbs.	Muriate of potash	20 lbs.
Acid phosphate	261 lbs.	Acid phosphate	300 lbs.
Cotton-seed meal	286 lbs.	Nitrate of soda	64 lbs.
		Cotton-seed	13⅓ bush.
Kainit	64 lbs.	Kainit	45 lbs.
Acid phosphate	273 lbs.	Acid phosphate	264 lbs.
Cotton-seed meal	143 lbs.	Cotton-seed	26⅔ bush.
Cotton-seed	13⅓ bush.		
		Commercial fertilizer to analyze as below:	
Acid phosphate	266 lbs.	Available phosphoric acid	10.00
Nitrate of soda	13 lbs.	Ammonia	4.85
Stable manure	4,000 lbs.	Potash (K_2O)	3.00
		Use 500 pounds per acre.	

All cotton formulas that do not include nitrate of soda should receive an application of this material at the rate of 50 pounds per acre, when the plants start growth, in sections infested with the Boll Weevil.

COTTON FORMULA SOLD BY MANUFACTURERS.

Avail. phos. acid	8.00 per cent. from	Acid phosphate	300-600 lbs. per acre.
Nitrogen	1.65 per cent. from	Nitrate of soda and Cotton-seed meal	
Potash	2.00 per cent. from	Kainit	

This formula or one very similar to it, is used extensively and only small amounts of nitrate of soda are used when this material is included.

Tobacco is a crop that must be fertilized very carefully to prevent injuring the flavor of the leaf. Chlorine seems to be detrimental to the production of good flavored leaf. Therefore muriate of potash, kainit and sylvinit must not be used. The potash may be furnished from sulphate of potash, carbonate of potash, or from cotton hull and wood ashes. Nitrogen as nitrate or organic nitrogen from dried blood, cotton-seed meal, castor pomace and linseed meal are excellent. These nitrogenous fertilizers are often combined so as to supply available nitrogen during the whole growing period. Phosphoric acid in the available form is best suited for this crop. Most of the high priced tobacco is grown on light soils which are rather deficient in fertility. Large applications of complete fertilizers are essential although excessive amounts should be avoided to produce profitable yields. Farm manures and green manures tend to produce a coarse leaf which is undesirable for grades of high quality.

Florida Tobacco Formulas.

No. 1.

	Per cent.
300 lbs. of carb. of pot. (60 per cent.)	
400 lbs. of tobacco dust (2-5)	3.05 ammonia
200 lbs. of cotton-seed meal (7½-2½-1½)	8.95 available
750 lbs. of bone-meal (4-10)	10.50 potash
300 lbs. of concentrated phos. (25 per cent.)	
50 lbs. of nitrate of soda (17 per cent.)	
2,000	

Commercial value per ton mixed and bagged.. $38.30
Plant food per ton.......................... 440 pounds.

No. 2.

	Per cent.
300 lbs. of nitrate of potash (13-42)	
100 lbs. of carb. of pot. (60 per cent.)	3.05 ammonia
800 lbs. of tobacco dust (2-3)	8.95 available
200 lbs. of bone-meal (3-12)	10.50 potash
600 lbs. of concentrated phos. (25 per cent.)	
2,000	

Commercial value mixed and bagged......... $38.30
Plant food per ton.......................... 440 pounds.

No. 3.

		Per cent.
400 lbs. of nitrate of potash (13-42)		
100 lbs. of cotton-seed meal (7½-2½-1½)		4.20 ammonia
700 lbs. of tobacco dust (2-5)		9.45 available
100 lbs. of bone-meal (3-12)		10.20 potash
700 lbs. of concentrated phos. (25 per cent.)		
2,000		

Commercial value mixed and bagged $37.15
Plant food per ton .... 477 pounds

No. 4.

	Per cent.
500 lbs. of nitrate of potash (13-42)	4.45 ammonia
700 lbs. of tobacco dust (2-3)	10.00 available
800 lbs. of concentrated phos. (25 per cent.)	11.55 potash
2,000	

Commercial value mixed and bagged $39.50
Plant food per ton .... 520 pounds

No. 5.

300 lbs. of cotton-seed meal
150 lbs. of nitrate of soda
300 lbs. of acid phosphate
200 lbs. of sulphate of potash

Part of the nitrate of soda may be applied after the plant has started growth.

Connecticut Tobacco Formula—Per Acre.

100 lbs. nitrogen from { Mixtures of nitrate of soda, sulphate of ammonia and high grade organic forms.
75 lbs. avail. phos. acid from superphosphates
150 lbs. potash from sulphate of carbonate forms.

Kentucky and Virginia on heavier soils may give good yields with smaller applications than for Connecticut.

Sempers recommends a formula furnishing 1,000-2,000 pounds per acre, of

Nitrogen	5-7 per cent. from	Nitrate of soda
Avail. phos. acid	5-6 per cent. from	Dissolved bone-black
Potash	8-11 per cent. from	Cotton-seed hull ashes, or Wood ashes, or Sulphate of potash.

Sugar-cane is another crop which is grown in limited areas. The Louisiana Sugar Experiment Station has investigated the

needs of this crop. It is customary to rotate this crop with corn and cowpeas. Cane is grown for two years as plant and first year stubble, and corn the third year with cowpeas sown between the rows at the last cultivation. The cowpeas are usually fed to the plantation mules but the roots and more or less of the plants are left on the land.

SUGAR-CANE FORMULA WITH COWPEAS. PLANT CANE 300-400 POUNDS. ACID PHOSPHATE PER ACRE.

1st year stubble	200 lbs. acid phosphate 200 lbs. cotton-seed meal, or tankage	per acre.

WITHOUT COWPEAS

Plant cane	200 lbs. acid phosphate 200 lbs. cotton-seed meal, or tankage	per acre
1st year stubble	100 lbs. acid phosphate 200 lbs. cotton-seed meal, or tankage	per acre.

FLORIDA FORMULA.

400 to 500 lbs. cotton-seed meal 50 to 100 lbs. nitrate of soda 300 to 400 lbs. acid phosphate 100 to 150 lbs. kainit	per acre

Part of the nitrate of soda in this last formula may be used as a second application after the plants have started.

Sugar-cane has a long growing season and the nitrogen therefore is furnished mostly from organic sources so as to be able to supply available nitrogen during this period.

Although sugar-cane requires available potash the Louisiana cane lands are sufficiently supplied with this constituent to meet the requirements of this crop.

SUGAR-CANE FORMULA–SEMPER MANURES–600-900 POUNDS PER ACRE.

Nitrogen	1.5-2 per cent. from	Nitrate of soda and Cotton-seed meal
Avail. phos. acid	7-9 per cent. from	Acid phosphate, or Dissolved bone-black
Potash	7-9 per cent. from	Muriate of potash, or Kainit

Irish potatoes are an exhaustive crop from the fertility standpoint, but from the money value viewpoint they are less exhaustive than the small grains. They are grown as an early and late crop in the North and in the South they are generally

most profitable when harvested in very early spring. They are usually grown in rotation and the early crops are forced by heavy fertilization, while the late crops are allowed to grow slowly and with less fertilizer. Potash is an important constituent for potatoes as it aids in carbohydrate formation. The chlorides seem to produce inferior potatoes and potatoes that will not stand storage. The sulphates of potash seem to produce better looking and more uniform potatoes. For early spring potatoes the nitrogen may be supplied partly in quickly available forms and partly from organic substances as dried blood, cottonseed meal, etc. The late potatoes do not require quickly available plant food as they have a long growing season. Excessive nitrogen should be avoided as the vines will grow too vigorously and the tubers will not develop. Phosphoric acid from superphosphates is desirable for early and late potatoes.

FORMULAS FOR IRISH POTATOES—500-1,500 LBS. PER ACRE.

Nitrogen 4-6 per cent. from	Nitrate of soda and Dried blood
Available phosphoric acid 5-7 per cent. from	Acid phosphate, or Dissolved bone-black
Potash 7-9 per cent. from	Sulphate of potash

EARLY POTATOES—800-2,000 LBS. PER ACRE.

Nitrogen 3-4 per cent. from available forms
Available phosphoric acid 6-8 per cent. from superphosphate.
Potash 8-10 per cent. from sulphate of potash.

This formula is employed in New York and New Jersey.

LATE POTATOES—600-800 LBS. PER ACRE.

Nitrogen 2.5 per cent.
Available phosphoric acid 6 per cent.
Potash 8 per cent.

MAINE POTATOES HARVESTED IN EARLY SEPT.—1,200-1,500 LBS. PER ACRE.

Ammonia 4-6 per cent.
Available phosphoric acid 6-8 per cent.
Potash 7-10 per cent.

The potatoes that receive this formula follow clover sod which is turned under in the fall. Some farmers in Maine use higher quantities of ammonia to force growth in that northern latitude and potash to benefit the clover which follows.

LOUISIANA POTATOES HARVESTED IN EARLY MAY—1,000-1,500 LBS. PER ACRE.

500-600 lbs. cotton-seed meal
500-600 lbs. acid phosphate.
175-200 lbs. sulphate of potash.

The Louisiana soils are rich in potash but for heavy yields the addition of sulphate of potash is beneficial. This formula is for an average soil with no cowpeas plowed under.

WITH COWPEAS—TURNED UNDER—800-1,000 LBS. PER ACRE.

500:600 lbs. acid phosphate.
175-200 lbs. sulphate of potash.

Sweet Potatoes.—In the growing of sweet potatoes the northern market demands must be catered to. A small rather round potato that is dry and mealy when baked is desirable. In the South a larger more oblong potato is relished. The phosphoric acid and potash requirements are about the same as for Irish potatoes except that chlorides may be used. As short round potatoes are desired, less nitrogen must be used than in growing Irish potatoes. When large amounts of nitrogen are used the potatoes grow too large and oblong. In the South nitrogen as nitrates and organic forms are used. The organic nitrogen seems to produce a better product and may be used to advantage in the South, but in the North, nitrates are preferable especially in cold seasons.

FORMULAS FOR SWEET POTATOES.

REQUIREMENT—3 PER CENT. AMMONIA, 7 PER CENT. AVAILABLE PHOSPHORIC ACID AND 8 PER CENT. POTASH.

100 lbs. nitrate of soda	will yield	3.5%	ammonia
400 lbs. dried fish scrap		7.8	avail. phos. acid
1,180 lbs. acid phosphate, 11%		8.3	potash
320 lbs. muriate of potash			
2,000 lbs.			

100 lbs. nitrate of soda	will yield	3.5%	ammonia
500 lbs. cotton-seed meal		7.8	avail. phos. acid
1,100 lbs. acid phosphate, 13%		8.3	potash
300 lbs. muriate of potash			
2,000 lbs.			

320 lbs. acid phosphate	per acre
360 lbs. cotton-seed meal	
640 lbs. kainit	
1,320 lbs.	

This last formula is perhaps too high in nitrogen for the production of sweet potatoes for the northern market.

FOR "VINELAND SWEETS."

Nitrogen 3 per cent. Available phosphoric acid 7 per cent. Potash 12 per cent.	Heavy applications.

Sometimes applications of 200-300 pounds of acid phosphate and 100 to 150 pounds of muriate of potash per acre are used to supplement this last formula.

200 lbs. sulphate of ammonia 200 lbs. dried blood, or 300 lbs. fish scrap 1,200 lbs. acid phosphate. 11% 400 lbs. high grade sulphate of potash	4.25% nitrogen 6.60 phos. acid 10.00 potash	200-1,000 lbs. per acre

Sugar-Beet.—When sugar-beets are grown for sugar the subject of proper fertilization is important. The sugar-beet is a gross feeder. A large yield of sugar is the desirable object in the growth of this crop. Potash aids in the formation of carbohydrates and is the important constituent for this crop. Sugar-beets should be forced early in the season and continuous growth should be avoided as it tends to reduce the sugar content. Organic nitrogenous materials are not so desirable as nitrate of soda and sulphate of ammonia. Farm manure is not beneficial for this crop as it is too lasting. Available phosphoric acid seems to favor early growth in sugar-beets and is therefore desirable. Potash as sulphate seems to give better results than chlorides.

FORMULA FOR SUGAR-BEETS.

250-300 lbs. nitrate of soda 400-500 lbs. superphosphate 80-100 lbs. sulphate of potash	applied in two or three dressings per acre

The nitrogen may be supplied partly from nitrate of soda and partly from sulphate of ammonia. On light soils the above amounts may be increased one-third.

Sorghum.—When this crop is grown for sugar it must be fertilized to produce it. As potash helps in sugar formation a large percentage of this constituent is necessary. The chloride seems to be the best form of potash for sorghum. The nitrogen should be applied early to produce growth but an excess must be avoided so as not to interfere with the formation of sugar. Liberal

amounts of phosphoric acid are beneficial in the growing and maturing of this crop.

FORMULA FOR SORGHUM (FOR SUGAR)—400 TO 500 LBS. PER ACRE.

Nitrogen 3.5-4.5 per cent. from nitrate of soda.
Available phosphoric acid 8-9 per cent. from acid phosphate.
Potash 8-9 per cent. from muriate of potash.

Peanuts.—This is a leguminous crop and a good nitrogen gatherer. Phosphoric acid and potash are necessary for this crop. Organic matter seems to be desirable and stable manure may be applied to the crop that precedes peanuts. If stable manure is applied directly to peanuts, too vigorous a growth of vines and poor pods result. Soils well stocked with humus do not require nitrogen but a small amount of this constituent is often beneficial. Rich soils do not require much fertilizer.

FORMULA FOR PEANUTS—200 TO 1,000 LBS. PER ACRE.

Nitrogen 2-4 per cent. from	Nitrate of soda
Available phosphoric acid 5-7 per cent. from	Acid phosphate
Potash 6-10 per cent. from	Muriate of potash, or Wood ashes, or Kainit

An abundance of lime is required in peanut culture. Soils deficient in lime should receive applications of 1,000 to 2,000 per acre every four or five years.

Flax is a weak feeder and requires a soil well tilled and fertilized. This crop cannot be successfully grown on the same land only once in four or five years. It seems to put the soil in poor condition for its own continual growth. Flax does well when following corn which has received liberal applications of farm manure. Conditions favorable for wheat culture meet the requirements of this crop.

Hops is a crop that requires plant food in a readily available form. Farm manure supplemented with light applications of fertilizer are beneficial. A fertilizer made up of a mixture of muriate of potash, superphosphate, nitrate of soda, and organic nitrogenous material may be used for this crop.

FORMULA FOR HOPS—800 TO 1,200 LBS. PER ACRE.

Nitrogen 2.5-3.5 per cent. from	Nitrate of soda Organic nitrogen
Available phosphoric acid 5-6 per cent. from	Superphosphate
Potash 12-14 per cent. from............ ...	Muriate of potash

Lawns.—In the fertilization of lawns it is necessary to encourage the growth of grasses rather than legumes. In preparing to seed a lawn, a very rich soil should be established. This may be done by applying an abundance of well rotted farm manure and thoroughly incorporating it in the soil. Green manures may be substituted in the absence of farm manure. To supplement the farm manure, applications of 1,000 to 1,500 pounds per acre of a fertilizer made up of nitrate of soda or sulphate of ammonia, bone-meal, and muriate of potash or kainit, should be added. The nitrogen from nitrate of soda or sulphate of ammonia should only be supplied in small amounts. An application of 800 to 1,000 pounds of lime per acre is also beneficial.

In the fall it is well to put on a top dressing of farm manure and rake off the straw, etc., in the spring. Some people object to the odor of farm manure and in such cases a fertilizer made up of bone-meal, and kainit or muriate of potash may be used. In the spring a light dressing of nitrate of soda will help the grass to get a good start. It is often advisable to make two or three applications of nitrate of soda as needed. For old lawns, 500 to 700 pounds of a complete fertilizer analyzing 3 per cent. of nitrogen, 8 per cent. of available phosphoric acid, and 5 per cent of potash is beneficial. Wood ashes make a desirable lawn fertilizer when supplemented with nitrate of soda.

In applying fertilizer to lawns great care should be exercised to broadcast it evenly, otherwise a uniform growth will not be secured. This may be accomplished by applying one-half of it walking east and west and the other half walking north and south.

2. Forage Crops.

Under this head come those crops that are grown for feeding farm animals, particularly when the whole plant is used. They are fed as soiling crops, ensilage, pasturage, hay, fodder and roots.

Soiling Crops.—These are grown a great deal for furnishing green succulent feed to dairy cows. The most desirable soiling crops are those that grow rapidly and come up again after being cut. These crops should be fertilized to produce rapid growth and not for grain and seed. The soiling crops may be divided into non-leguminous and leguminous.

Non-Leguminous Crops.—Of the non-leguminous soiling crops the cereals, rye, oats, wheat and barley are often used. Corn, sorghum, and millet are also very important and teosinte is used occasionally. These crops require considerable nitrogen to produce the necessary vigorous growth and an abundance of phosphoric acid and potash. When they follow crops that have been well fertilized the amount to supply depends upon what is available in the soil. With the cereals a rank growth of stalk is desired so that fertilization is different from what is desirable in the production of grain. More nitrogen is needed than for grain production, phosphoric acid is important, and potash on those soils deficient in this element. At seeding time small applications of nitrogen and phosphoric acid in available forms are desirable. Some of the legumes as vetch and peas are often grown with the cereals. The fertilization in such mixtures must be ample to produce good crops. The nitrogen content may be lessened somewhat, but phosphoric acid and potash should predominate and occasionally lime is necessary.

Sorghum.—When this crop is grown for forage it must be fertilized differently than when grown for sugar. The needs of this crop are similar to corn forage. Well rotted farm manure or a leguminous green manure help to produce good sorghum forage. Applications of available phosphoric acid and potash, as muriate or kainit, are good supplements of farm or green manures. A light dressing of nitrate of soda or sulphate of ammonia when the plants have started helps in early growth.

FORMULA FOR SORGHUM FORAGE—650-750 POUNDS PER ACRE.

Nitrogen	3.5-4.5 per cent. from	Nitrate of soda
Avail. phos. acid	5.5-6.5 per cent. from	Acid phosphate
Potash	4-5 per cent. from	Muriate of potash, or Kainit

Leguminous Crops.—These crops require liberal supplies of potash, lime and phosphoric acid. As they are able to secure nitrogen from the air, this element does not need to be furnished except occasionally at seeding time, in a quickly available form. When legumes follow crops that have been well fertilized they often grow well without any additional fertilizer on rich land. There seems to be a mistaken belief among some farmers, that the legumes ought to grow well without any fertilizer, especially when following a harvested crop. A little available nitrogen when the plants start growth helps to produce a plant that is better able to secure nitrogen from the air, and applications of phosphoric acid and potash tend to increase the yields on most soils.

FORMULAS FOR LEGUMES—ALFALFA.

500 lbs. acid phosphate 100 lbs. sulphate of ammonia 350 lbs. muriate of potash Lime when needed	per acre

CLOVERS.

300 lbs. acid phosphate 200 lbs. muriate of potash 50 lbs. nitrate of soda Lime when necessary	per acre.

CLOVER AND LEGUMES—400-800 POUNDS PER ACRE.

Nitrogen	1-2 per cent. from	Nitrate of soda, or Sulphate of ammonia
Avail. phos. acid	6-8 per cent. from	Dissolved bone-meal, or Acid phosphate
Potash	8-10 per cent. from	Wood ashes, or Muriate of potash

COWPEA, SOY BEAN AND VETCH.

200 lbs. acid phosphate 100 lbs. muriate of potash	per acre

Nitrate of soda is sometimes beneficial to start vigorous growth.

VELVET BEAN.

50 lbs. nitrate of soda, or 100 lbs. cotton-seed meal 200 lbs. acid phosphate 100 lbs. sulphate of potash	per acre

Scheme of Soiling Crops.—The New Jersey Experiment Station has conducted a rotation of soiling crops which gives interesting

data on the kinds and amounts of fertilizers used to furnish plenty of plant food for the production of satisfactory crops.

SCHEME OF SOILING CROPS.

No. of acre	Crop rotation	Time of seeding	Amount of fertilizer applied	Time of harvesting
1	Crimson clover,	Aug. 11, '97	100 lbs. acid phosphate 50 lbs. muriate of pot.	May 20, '98
	Corn..........	June 20, '98	100 lbs. acid phosphate 50 lbs. ground bone 50 lbs. muriate of pot.	Aug. 20, '98
	Barley and peas.	Aug. 25, '98	25 lbs. nitrate of soda 100 lbs. acid phosphate 50 lbs. muriate of pot.	Oct. 25, '98
2	Crimson clover,	Aug. 24, '97	100 lbs. acid phosphate 50 lbs. muriate of pot.	May 10, '98
	Corn...........	June 10, '98	100 lbs. acid phosphate 50 lbs. ground bone 50 lbs. muriate of pot.	Aug. 10, '98
	Barley and peas,	Aug. 25, '98	25 lbs. nitrate of soda 100 lbs. acid phosphate 50 lbs. muriate of pot.	Oct. 25, '98
3	Corn...........	May 20, '98	50 lbs. nitrate of soda 100 lbs. acid phosphate 50 lbs. ground bone 50 lbs. muriate of pot.	July 20, '98
	Millet...........	Aug. 1, '98	75 lbs. nitrate of soda 150 lbs. acid phosphate 75 lbs. muriate of pot.	Oct. 1, '98
4	Corn...........	May 10, '98	50 lbs. nitrate of soda 100 lbs. acid phosphate 50 lbs. ground bone 50 lbs. muriate of pot.	July 10, '98
	Barley and peas,	Aug. 10, '98	25 lbs. nitrate of soda 100 lbs. acid phosphate 50 lbs. muriate of pot.	Oct. 10, '98
5	Wheat.........	Sept. 28, '97	150 lbs. acid phosphate 50 lbs. ground bone 25 lbs. muriate of pot.	June 5, '98
	Oats and peas...	April 20, '98	25 lbs. nitrate of soda 100 lbs. acid phosphate 25 lbs. ground bone 50 lbs. muriate of pot.	June 20, '98
	Soy beans........	Aug. 1, '98	200 lbs. acid phosphate 100 lbs. muriate of pot.	Oct. 1, '98
6	Rye............	Sept. 29, '97	150 lbs. acid phosphate 50 lbs. ground bone 25 lbs. muriate of pot.	May 1, '98
	Millet...........	May 1, '98	75 lbs. nitrate of soda 150 lbs. acid phosphate 75 lbs. muriate of pot.	July 1, '98
	Cowpeas	July 20, '98	200 lbs. acid phosphate 100 lbs. muriate of pot.	Sept. 20, '98

SCHEME OF SOILING CROPS.—(*Continued*)

No. of acre	Crop rotation	Time of seeding	Amount of fertilizer applied	Time of harvesting
7	Oats and peas	April 10, '98	25 lbs. nitrate of soda 100 lbs. acid phosphate 25 lbs. ground bone 50 lbs. muriate of pot.	June 10, '98
	Soy beans	July 1, '98	200 lbs. acid phosphate 100 lbs. muriate of pot.	Sept. 1, '98
	Barley and peas	Sept. 1, '98	25 lbs. nitrate of soda 100 lbs. acid phosphate 50 lbs. muriate of pot.	Nov. 1, '98
8	Oats and peas	April 1, '98	25 lbs. nitrate of soda 100 lbs. acid phosphate 25 lbs. ground bone 50 lbs. muriate of pot.	June 1, '98
	Cowpeas	June 15, '98	200 lbs. acid phosphate 100 lbs. muriate of pot.	Aug. 15, '98
	Barley and peas	Aug. 20, '98	25 lbs. nitrate of soda 100 lbs. acid phosphate 50 lbs. muriate of pot.	Oct. 20, '98
9	Rye and vetch	Sept. 10, '97	25 lbs. nitrate of soda 150 lbs. acid phosphate 75 lbs. muriate of pot.	May 5, '98
	Corn	June 1, '98	100 lbs. acid phosphate 50 lbs. ground bone 50 lbs. muriate of pot.	Aug. 1, '98
	Barley and peas	Aug. 15, '98	25 lbs. nitrate of soda 100 lbs. acid phosphate 50 lbs. muriate of pot.	Oct. 15, '98

Rape is often used as a soiling crop. It is a vigorous feeder and capable of obtaining food more readily than cereal crops. Nitrogen in available forms helps this crop in early growth. It requires phosphoric acid and abundant supplies of potash.

FORMULA FOR RAPE.

Nitrogen	2-3 per cent. from	Nitrate of soda Dried blood
Avail. phos. acid,	4-5 per cent. from	Superphosphate
Potash	4-5 per cent. from	Muriate of potash, or Kainit.

Ensilage.—In the production of corn for ensilage the formation of ears is desirable and the crop should be fertilized somewhat the same as field corn. More nitrogen is needed however for silage than for field corn, because a larger growth of stalk is required. Legumes are often mixed with corn and sorghum in growing crops for ensilage. The legumes require liberal supplies of phosphoric acid and potash.

FORMULA FOR SILAGE CORN.

450 pounds cotton-seed meal, or	per acre
250 pounds dried blood	
300 pounds acid phosphate	
120 pounds muriate of potash	

Pasturage.—In applying fertilizers to pastures the main object is to produce growth of legumes and grasses. If too much nitrogen is supplied the grasses will crowd out the legumes. It should therefore be better to encourage the growth of the legumes as these furnish the richer feed. Mixtures of bone-meal, acid phosphate, muriate of potash and kainit, are excellent for pastures. An occasional dressing of lime is sometimes essential.

Hay and Grass Crops.—Grass crops do well when supplied with complete fertilizers. Nitrogen is essential for vigorous growth and a little nitrate of soda is very beneficial in helping grass to recover from a severe winter. These crops feed close to the surface and are unable to search and obtain mineral food unless it is supplied. Phosphoric acid and potash help a great deal in increasing the yields. Stable manure, ground bone and muriate potash are very beneficial.

FORMULA FOR GRASS CROPS.

Nitrogen,	5-6 per cent. from	Nitrate of soda and Dried blood, or Raw bone-meal.
Avail. phos. acid	5-6 per cent. from	Raw bone-meal, or Basic slag, or Acid phosphate.
Potash	7-8 per cent. from	Wood ashes, or Kainit

Roots.—Turnips, fodder beets, rutabagas, mangels, carrots, sugar-beets, etc., are grown for feeding live-stock. They assimilate large amounts of plant food and liberal fertilization is necessary for the production of large yields. Fodder beets, carrots and sugar-beets need plenty of nitrogen and phosphoric acid to keep up a rapid and continuous growth. Potash is required on soils deficient in this constituent and especially on light soils. The nitrogen and phosphoric acid should be in readily available forms so as to help in early growth. Mangels are perhaps the largest feeders and seem to be able to secure phos-

phoric acid from the soil. Turnips cannot secure phosphoric acid as well as mangels and they feed also more from the surface soil. The turnip uses a great deal of potash. Nitrogen is necessary for early, rapid, and continuous growth in all root crops.

Irish and sweet potatoes when grown for stock feed require the same fertilization as when produced for market. Usually these crops are not fed to stock unless the market price is too low to warrant shipping.

FORMULAS FOR ROOTS. MANGELS—400-800 POUNDS PER ACRE.

Nitrogen	5-6 per cent. from	Nitrate of soda
Avail. phos. acid	5-6 per cent. from	Dissolved bone-black, or Acid phosphate
Potash	7-9 per cent. from	Sulphate of potash.

TURNIPS (RUTABAGAS)—300-800 POUNDS PER ACRE.

Nitrogen	4-5 per cent. from	Nitrate of soda Dissolved bone-meal
Avail. phos. acid	6-7 per cent. from	Dissolved bone-meal, or Dissolved bone-black, or Acid phosphate.
Potash	7-9 per cent. from	Wood ashes, or Muriate of potash.

FODDER BEETS AND SUGAR-BEETS—1,000 POUNDS PER ACRE.

Nitrogen	4 per cent.
Available phosphoric acid	5 per cent.
Potash	10 per cent.

3. Market Garden and Truck Crops.

Requirements.—These crops require large applications of high grade fertilizers because they are usually forced for an early market. If these crops are late most of the profits are lost. Many of these truck crops are grown on sandy, or light soils, which are naturally deficient in fertility. Market garden crops are often grown near cities on high priced land which necessitates early and large yields to make them pay. An excess of all the constituents should be furnished to be certain that enough plant food is present. Part of the nitrogen in fertilizers for these crops should be as nitrate to give the plants an early start as these crops are often grown in the spring before the nitrate forming organisms are active.

It will rarely ever pay to be too economical in the amount of fertilizer to use. Less than 500 pounds per acre is not usually sufficient and 1,000 to 2,000 pounds are often profitable in crop returns. The following formulas are figured for applications of 2,000 pounds and the market gardener or trucker should use his own judgment as to the amount to use. Those plants having equal requirements are grouped together.

FORMULAS FOR MARKET GARDEN AND TRUCK CROPS.

Asparagus and Rhubarb.

Requirement—ammonia, 5 per cent.; available phosphoric acid, 7 per cent.; potash, 8 per cent.

700 lbs. cotton-seed meal 200 lbs. nitrate of soda 800 lbs. acid phosphate, 13 % 300 lbs. muriate of potash	will yield	4.9 % ammonia 6.1 % avail. phos. acid 8.4 % potash
2,000 ibs.		

Nitrogen	4-5 per cent. from	Nitrate of soda and Dried blood Dissolved bone-meal	400-800 lbs. per acre.
Avail. phos. acid	6-7 per cent. from	Superphosphate and Basic slag	
Potash	7-9 per cent. from	Wood ashes, or Kainit.	
Nitrogen	4 per cent. from	Nitrate of soda and Dried blood, or Cotton-seed meal	1,000-1,500 lbs. per acre.
Phosphoric acid	8 per cent. from	Superphosphate and Ground bone, or Tankage	
Potash	10 per cent. from	Muriate of potash	

Beans and Peas.

Requirement—ammonia, 3 per cent.; available phosphoric acid, 7 per cent.; potash, 7 per cent.

100 lbs. nitrate of soda 450 lbs. cotton-seed meal 1,200 lbs. acid phosphate, 11 % 250 lbs. muriate of poiash	will yield	2.9 % ammonia 7.1 % avail. phos. acid 6.9 % potash.
2,000 lbs.		

Nitrogen	1-2 per cent. from	Nitrate of soda, or Sulph. of ammo. and Dried blood	400-800 lbs. per acre.
Avail. phos. acid	6-9 per cent. from	Superphosphate	
Potash	7-9 per cent. from	Wood ashes, or Muriate of potash, or Kainit	

Beans and peas are leguminous crops and can secure nitrogen from the air. Nitrogen should be added to allow of a long harvesting period and to produce quick and steady growth.

Beets and Lettuce.

Requirement—ammonia, 6 per cent.; available phosphoric acid, 5 per cent.; potash, 8 per cent.

300 lbs. nitrate of soda 800 lbs. cotton-seed meal 600 lbs. acid phosphate, 13 % 300 lbs. muriate of potash	will yield	6.2 % ammonia 4.9 % avail. phos. acid 8.5 % potash.
2,000 lbs.		

200 lbs. nitrate of soda 800 lbs. fish scrap 700 lbs. acid phosphate, 11 % 300 lbs. muriate of potash	will yield	5.9 % ammonia 5.4 % avail. phos. acid 7.8 % potash.
2,000 lbs.		

Lettuce.

Nitrogen	5-6 per cent. from	Three forms Nitrate of soda and Sulph. of ammo. and Organic nitrogen	900-1,500 lbs. per acre.
Avail. phos. acid	5-6 per cent. from	Superphosphate	
Potash	8-10 per cent. from	Wood ashes, or Muriate of potash	

Cabbage, Cauliflower, Cucumbers, Melons and Brussel Sprouts

Requirement—ammonia, 6 per cent.; available phosphoric acid, 5 per cent.; potash, 7 per cent.

300 lbs. nitrate of soda 750 lbs. cotton-seed meal 700 lbs. acid phosphate, 11 % 250 lbs. muriate of potash	will yield	6.0 % ammonia 4.8 % avail. phos. acid 7.1 % potash
2,000 lbs.		

Cabbage and Cauliflower.

Nitrogen	4-6 per cent. from	Three forms Nitrate, ammonia and Organic	800-2,000 lbs. per acre.
Avail. phos. acid	5-7 per cent. from	Superphosphate	
Potash	7-9 per cent. from	Wood ashes, or Muriate of potash.	

Cucumbers.

Nitrogen	4.5-5 per cent. from	Three forms Nitrate, ammonia and Organic	1,000-1,500 lbs. per acre.
Avail. phos. acid	5-6 per cent. from	Superphosphate	
Potash	6-8 per cent. from	Wood ashes, or Muriate of potash	

Melons.

Nitrogen	5-6 per cent. from	Nitrate of soda Dissolved bone-meal	500-1,500 lbs. per acre.
Avail. phos. acid	5-6 per cent. from	Dissolved bone-meal, or Dissolved bone-black, or Acid phosphate	
Potash	7-9 per cent. from	Wood ashes, or Muriate of potash	

Celery.

Requirement—ammonia, 7 per cent.; available phosphoric acid, 5 per cent.; potash, 8 per cent.

300 lbs. nitrate of soda 800 lbs. fish scrap 600 lbs. acid phosphate, 13 % 300 lbs. Muriate of potash	will yield	6.9 % ammonia 5.5 % avail. phos. acid 7.5 % potash.
2,000 lbs.		

250 lbs. nitrate of soda 600 lbs. dried blood 850 lbs. acid phosphate, 13 % 300 lbs. muriate of potash	will yield	7.2 % ammonia 5.5 % avail. phos. acid 7.5 % potash.
2,000 lbs.		

Nitrogen	5-6 per cent. from	Three forms Nitrate, ammonia and Organic	1,000-1,500 lbs. per acre.
Avail. phos. acid	5-6 per cent. from	Superphosphate	
Potash	8-10 per cent. from	Wood ashes, or Muriate of potash.	

Egg Plant and Tomatoes.

Requirement—ammonia, 5 per cent.; available phosphoric acid, 6 per cent.; potash, 7 per cent.

200 lbs. nitrate of soda 700 lbs. cotton-seed meal 840 lbs. acid phosphate, 13 % 260 lbs. muriate of potash	will yield	4.9 % ammonia 6.3 % avail. phos. acid 7.4 % potash.
2,000 lbs.		

Tomatoes.

Nitrogen	4-6 per cent. from	Nitrate of soda Dried blood	500-1,000 lbs. per acre.
Avail. phos. acid	5-4 per cent. from	Superphosphate	
Potash	6-8 per cent. from	Wood ashes, or Muriate of potash	

Late Tomatoes.

400 lbs. nitrate of soda 700 lbs. bone tankage 400 lbs. acid phosphate 500 lbs. muriate of potash	1,000 lbs. per acre on average soil.
500 lbs. nitrate of soda 500 lbs. bone tankage 400 lbs. acid phosphate 600 lbs. muriate of potash	1,000 lbs. per acre on poor soil.

Onions, Onion Sets and Scullions.

Requirement—Ammonia, 5 per cent.; available phosphoric acid, 5 per cent.; potash, 8 per cent.

200 lbs. nitrate of soda 750 lbs. cotton-seed meal 750 lbs. acid phosphate, 11 % 300 lbs. muriate of potash	will yield	5.1 % ammonia 5.1 % avail. phos. acid 8.5 % potash.
2,000 lbs.		

Nitrogen	5-6 per cent. from	Nitrate of soda	900-1,800 lbs. per acre.
Avail. phos. acid	5-6 per cent. from	Dissolved bone-black Acid phosphate	
Potash	8-10 per cent. from	Wood ashes, or Muriate of potash	

Onion Sets and Scullions.

Nitrogen	5 per cent. from	Organic sources	1,000 lbs. per acre.
Avail. phos. acid	5 per cent. from	Bone or tankage	
Potash	10 per cent. from	Muriate of potash	

A top dressing of 75 to 100 pounds of nitrate of soda, or 60 to 75 pounds of sulphate of ammonia is recommended to supplement this last formula after the plants have started growth.

Pumpkins and Squashes.

Nitrogen	5-6 per cent. from	Organic sources and Nitrate of soda	500-1,500 lbs. per acre.
Avail. phos. acid	5-6 per cent. from	Superphosphate Basic slag	
Potash	7-9 per cent. from	Wood ashes, or Muriate of potash	

Radishes and Turnips.

Requirement—ammonia, 5 per cent.; available phosphoric acid.; 7 per cent.; potash, 8 per cent.

250 lbs. nitrate of soda 550 lbs. cotton-seed meal 900 lbs. acid phosphate, 13 % 300 lbs. muriate of potash	will yield	4.6 % ammonia 6.5 % avail. phos. acid 8.3 % potash.
2,000 lbs.		

Spinach.

Requirement—ammonia, 5 per cent.; available phosphoric acid, 8 per cent.; potash, 6 per cent.

200 lbs. nitrate of soda 650 lbs. fish scrap 950 lbs. acid phosphate, 14 % 230 lbs. muriate of potash	will yield	5.2 % ammonia 7.7 % avail. phos. acid 6.0 % potash.
2,oco lbs.		
300 lbs. nitrate of soda 500 lbs. cotton-seed meal 1,000 lbs. acid phosphate, 14 % 200 lbs. muriate of potash	will yield	5.0 % ammonia 7.6 % avail. phos. acid 5.6 % potash.
2,000 lbs.		

Applications of either of these formulas at the rate of 1,000 pounds per acre should be sufficient on average soils.

Strawberries—Florida.

200 lbs. nitrate of soda 300 lbs. dried blood 450 lbs. dissolved bone 350 lbs. acid phosphate 600 lbs. sulphate of potash	per acre.

The nitrate of soda should be applied when new growth starts in the spring and the remainder after harvest.

Strawberries—General Formula.

100 lbs. dried blood, or equivalents in nitrate of soda, or sulphate of ammonia 100 lbs. ground bone 100 lbs. acid phosphate 100 lbs. muriate of potash	500-800 lbs. per acre.

An addition of 100 pounds of nitrate of soda just before or after the plants have blossomed is recommended.

Sweet Corn.

Nitrogen	4 per cent from	Nitrate of soda Cotton-seed meal, or Dried blood, or Tankage	500-1,000 lbs. per acre.
Avail. phos. acid	8 per cent. from	Superphosphate	
Potash	10 per cent. from	Muriate of potash	

Farm manure may be used and it should be supplemented with phosphoric acid, potash, and available nitrogen.

4. Fruits.

In fertilizing fruits the main object is to produce enough growth of wood to make a strong vigorous tree or bush that will give profitable yields of fruit. As fruits often remain on the same land for years they exhaust the soil of fertility, which makes it necessary to furnish large quantities of plant food at the proper time to insure good yields. This may be well illustrated by an experiment conducted at the New Jersey Experiment Station with peaches. The soil was in good mechanical condition, of average fertility, and suitable for peach growing.

AMOUNT OF FERTILIZER APPLIED PER ACRE ANNUALLY.

	Pounds
Nitrate of soda	150
Dissolved bone-black	350
Muriate of potash	150
Amount of barnyard manure applied per acre annually	20 tons

1. THE YIELD WITHOUT MANURE.

	Baskets per acre
1884-1891, inclusive, 8 years, average per year	65.7
1884-1895, inclusive, 10 years, average per year	60.3
1887-1891, inclusive, (5 crop years) average per year	105.0
1887-1893, inclusive, (7 crop years) average per year	86.2

2. THE YIELD WITH COMPLETE CHEMICAL FERTILIZER.

1884-1891, inclusive, 8 years, average per year	164.2
1884-1893, inclusive, 10 years, average per year	183.4
1887-1891, inclusive, (5 crop years) average per year	262.8
1887-1893, inclusive, (7 crop years) average per year	262.0

3. THE YIELD WITH BARNYARD MANURE.

1884-1891, inclusive, 8 years, average per year	169.5
1884-1893, inclusive, 10 years, average per year	194.7
1887-1891, inclusive, (5 crop years) average per year	271.3
1887-1893, inclusive, (7 crop years) average per year	276.8

4. THE RELATIVE YIELD IN AN UNFAVORABLE SEASON.

1889, unmanured	10.9
1889, fertilized	152.5
1889, manured	162.5

These results show that the yields were much larger when the trees were fertilized. The effect of the fertilizer and the barn-

yard manure were practically the same, showing that both are satisfactory for fertilizing peaches.

In many orchards cover crops of rye, oats, clover, or other legumes are sown in the mid-summer which absorb the moisture and assimilate the available plant food in the soil causing the growth of the tree to cease and the buds to mature. Early in the spring cover crops should be plowed under to add plant food to the soil and to enable the trees to utilize it early enough so as not to interfere with the forming of fruit.

As fruits are slow in growing the nitrogen may be supplied chiefly from organic sources. Nitrate of soda or sulphate of ammonia are sometimes necessary to help the trees in the spring or at such times in the early summer when they lack vigor which is indicated to some extent by the yellow color of the leaves. Organic nitrogen applied from artificial fertilizing materials or from green manures should be applied or turned under in the early spring so that the nitrogen will decompose and be utilized, so as not to prolong growth and interfere with the formation of fruit. Young trees and bushes require more nitrogen than those that are mature or bearing. When legumes are plowed under the fertilizer may consist of phosphoric acid and potash, as sufficient nitrogen should be supplied by the green manure.

Steglich found that in every 100 parts of dry matter the following fertilizer constituents were required in pomaceous and stone fruits.

FOR POMACEOUS FRUITS (APPLES, PEARS, ETC.).

	Nitrogen	Phosphoric acid	Potash
Roots	0.349	0.101	0.234
Trunk and branches	0.597	0.126	0.313
Twigs (fruit bearing)	0.892	0.232	0.526
Leaves	0.719	0.214	1.194
Fruit	0.410	0.088	1.061

FOR STONE FRUITS (PEACHES, PLUMS, ETC.).

	Nitrogen	Phosphoric acid	Potash
Roots	0.370	0.115	0.206
Trunk and branches	0.307	0.081	0.193
Twigs (fruit bearing)	1.022	0.296	0.463
Leaves	1.725	0.336	2.579
Fruit	0.379	0.246	0.903

Trees ten inches in circumference require annually for their growth the following amounts of the essential elements.

	Nitrogen in ounces	Phosphoric acid in ounces	Potash in ounces
Pomaceous fruits	2.0	0.4	2.0
Stone fruits	2.0	0.4	2.6

Stone fruits often are benefited by additions of lime.

FORMULAS FOR FRUIT TREES.

Nitrogen	1.5-2 per cent. from	Nitrate of soda and Bone-meal	400-700 lbs. per acre
Avail. phos. acid	7-9 per cent. from	Dissolved bone-black, or Dissolved bone-meal, or Acid phosphate	
Potash	10-12 per cent. from	Wood ashes, or Kainit, or Muriate of potash	

For Apples and Pears, 10 Years Old.

250-500 lbs. bone-meal 50-150 lbs. nitrate of soda 100-300 lbs. sulphate of potash	per acre.
400-600 lbs. ground rock phosphate 100-300 lbs. nitrate of soda 100-300 lbs. sulphate of potash	per acre.

Apples, Pears, Plums and Peaches.

100 lbs. bone-meal 100 lbs. acid phosphate 100 lbs. muriate of potash	400 lbs. per acre of either formula for young trees.
150 lbs. bone-meal 100 lbs. muriate of potash	1,000-1,500 lbs. for bearing trees.

These last two formulas are recommended for fruit crops on average soils, but on light soils additions of more available nitro-

gen, phosphoric acid, and potash will be necessary. The first of these formulas is preferable on poor soils.

Cherries and Apricots.

150 lbs. bone-meal 100 lbs. muriate of potash Lime when needed	medium application.

Peaches, Georgia.

150 lbs. cotton-seed meal 50 lbs. sulphate of potash 50 lbs. acid phosphate	350 lbs. or more per acre.

Peaches, Florida.

1-5 lbs. cotton-seed meal 4-10 lbs. acid phosphate 3-6 lbs. sulphate of potash	to each tree.

For pears, 1,000 pounds of this last formula per acre, followed by 100 to 200 pounds of nitrate of soda when needed, is recommended for Florida conditions.

The citrous fruits respond quickly to fertilizers especially in Florida where much of the soil is very sandy. Potash in the form of chloride is unsuitable and organic sources of this constituent are also unsatisfactory. The fertilizers for citrous fruits are applied in two or three applications. Cover crops are often grown to conserve moisture and to furnish plant food. Dried blood is occasionally employed.

Oranges, Lemons, Kumquats and Loquats—Florida.

Ammonium sulphate,	200 lbs.	yields approximately	Nitrogen	4 %
Nitrate of soda,	150 lbs.		Avail. phos. acid	6 %
Dissolved bone-black, or	500 lbs.		Potash	12 %
Acid phosphate	640 lbs.			
Sulphate of potash	360 lbs.			

This should be applied per acre, or 20 pounds to a tree. It may be applied in three dressings; 1/4 in June, 1/4 in October and 1/2 in February.

Oranges and Lemons.

Nitrogen	4-6 per cent. from	Nitrate of soda, or Sulphate of ammonia
Avail. phos. acid	6-8 per cent. from	Dissolved bone-black, or Acid phosphate
Potash	8-10 per cent. from	Sulphate of potash

Grape Fruit.

10 lbs. nitrate of soda 4 lbs. acid phosphate 10 lbs. sulphate of potash	per bearing tree.

Bush Fruits.—Potash is the most important fertilizer constituent for bush fruits. The same principles of fertilization apply to this class as to pomaceous, stone and citrous fruits.

Raspberries, Blackberries, Gooseberries, Currants, Huckleberries and Barberries.

100 lbs. muriate of potash 100 lbs. nitrate of soda 150 lbs. acid phosphate	per acre.
100 lbs. muriate of potash 125 lbs. dried blood 250 lbs. ground rock phosphate, or 150 lbs. basic slag	per acre.

Blackberries—500-800 Pounds Per Acre.

Nitrogen	2-3 per cent. from	Nitrate of soda and Raw bone-meal
Avail. phos. acid	5-6 per cent. from	Dissolved bone-black, or Raw bone-meal
Potash	7-9 per cent. from	Wood ashes, or Kainit.

Raspberries—500-1,000 Pounds Per Acre.

Nitrogen	2.5-3 per cent. from	Nitrate of soda and Raw bone-meal
Avail. phos. acid	5-7 per cent. from	Dissolved bone-black, or Dissolved bone-meal, or Acid phosphate.
Potash	8-10 per cent. from	Wood ashes, or Kainit.

Grape, because of the large yields, is an exhaustive crop and requires liberal fertilization. Potash and phosphoric acid are especially required.

Grapes—500-700 Pounds Per Acre.

Nitrogen	1.5-2 per cent. from	Nitrate of soda and Raw bone-meal
Avail. phos. acid	7-9 per cent. from	Dissolved bone-black, or Dissolved bone-meal, or Raw bone-meal, or Acid phosphate
Potash	10-12 per cent. from	Wood ashes, or Muriate of potash, or Kainit

100 lbs. bone-meal 100 lbs. acid phosphate 100 lbs. muriate of potash	1,000-2,000 lbs. per acre
150 lbs. bone-meal 100 lbs. muriate of potash	1,000-2,000 lbs. per acre.

On light soils a dressing of 200 pounds of nitrate of soda is often desirable in the spring in addition to these last two formulas.

Miscellaneous Fruits.—Other fruits which are grown in some sections require special fertilization and a few formulas are given for reference.

Pineapples—2,000-3,000 Pounds Per Acre.

Nitrogen	3 per cent. from	Dried blood, or Cotton-seed meal
Phos. acid	7 per cent. from	Ground bone, or Basic slag, or Dissolved bone-black
Potash	7 per cent. from	Sulphate of potash

Apply in two dressings; one in February and the other in July.

Nitrogen	5 per cent. from	Cotton-seed meal, or Dried blood, or Castor pomace	3,500-4,000 lbs. per acre
Avail. phos. acid	4 per cent. from	Superphosphate	
Potash	10 per cent. from	Sulphate of potash	

This last formula should be applied in three or four dressings. When acid phosphate is used, lime at the rate of 750 pounds per acre is necessary every two years, because acid phosphate has an injurious effect on pineapples which lime corrects.

The banana plant requires a rich soil and some chlorine for best development. Potash seems to be beneficial and 300 pounds more than is included in the formula is sometimes helpful. The potash should be supplied as chloride.

Banana Formulas.

200 lbs. nitrate of soda 200 lbs. dried blood 500 lbs. acid phosphate 400 lbs. muriate of potash	per acre in two applications

Nitrogen	4-5 per cent. from	Nitrate of soda Cotton-seed meal	500-800 lbs. per acre.
Avail. phos. acid	6-8 per cent. from	Acid phosphate, or Superphosphate	
Potash	7-9 per cent. from	Kainit	

Japanese Persimmons.

Nitrogen	3 per cent.	5 lbs. to a tree.
Phosphoric acid	6 per cent.	
Potash	10 per cent.	

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Most any of the fertilizer materials are acceptable for this fruit. The nitrogen may be supplied from some leguminous green manure.

Olives—500-700 Pounds Per Acre.

Nitrogen	4-5 per cent. from	Nitrate of soda, or Sulphate of ammonia	500-700 lbs. per acre.
Avail. phos. acid	5-7 per cent. from	Dissolved bone-black, or Acid phosphate	
Potash	7-8 per cent. from	Muriate of potash, or Kainit	

Figs, Avocada Pear and Guava.—There is not much known about the requirements of these fruits but the following general formula is recommended.

300 lbs. nitrate of soda.
500 lbs. acid phosphate.
200 lbs. sulphate of potash.

Figs in addition to the above fertilizer requires a dressing of lime when the soil is deficient in this constituent. For guava, 600-1,000 pounds per acre of this formula are recommended.

Nuts.—Pecans do well on formulas furnishing:

Nitrogen	6 per cent. from	Cotton-seed meal, or Dried blood, or Tankage and Nitrate of soda
Avail. phos. acid	3 per cent. from	Acid phosphate, or Ground rock phosphate, or Bone-meal, or Basic slag.
Potash	3 per cent. from	Wood ashes, or Muriate of potash, or Kainit.

Most of the nitrogen can be furnished from organic sources with occasional applications of nitrate of soda or sulphate of ammonia when growth is needed in early spring. Black walnuts, chestnuts and other nuts may be fertilized similarly to pecans.

Cocoanuts.—This tree usually grows near the seashore, and seaweed may often be profitably utilized as a source of fertilizer.

TABLE SHOWING THE NUMBER OF POUNDS OF A FERTILIZER REQUIRED TO FURNISH ONE POUND OF ANY ELEMENT WHEN THE PERCENTAGE OF THAT ELEMENT PRESENT IN THE FERTILIZER IS KNOWN.[88]

Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required
0.1	1,000.00	4.4	22.73	8.7	11.49	13.0	7.692
0.2	500.00	4.5	22.22	8.8	11.36	13.1	7.634
0.3	333.33	4.6	21.74	8.9	11.24	13.2	7.576
0.4	250.00	4.7	21.28	9.0	11.11	13.3	7.512
0.5	200.00	4.8	20.83	9.1	10.99	13.4	7.463
0.6	166.67	4.9	20.41	9.2	10.87	13.5	7.407
0.7	142.86	5.0	20.00	9.3	10.75	13.6	7.353
0.8	125.00	5.1	19.61	9.4	10.64	13.7	7.299
0.9	111.11	5.2	19.23	9.5	10.53	13.8	7.246
1.0	100.00	5.3	18.87	9.6	10.42	13.9	7.194
1.1	90.91	5.4	18.52	9.7	10.31	14.0	7.143
1.2	83.33	5.5	18.18	9.8	10.20	14.1	7.092
1.3	76.92	5.6	17.86	9.9	10.10	14.2	7.042
1.4	71.43	5.7	17.54	10.0	10.00	14.3	6.993
1.5	66.63	5.8	17.24	10.1	9.901	14.4	6.944
1.6	62.50	5.9	16.95	10.2	9.804	14.5	6.897
1.7	58.82	6.0	16.67	10.3	9.709	14.6	6.849
1.8	55.56	6.1	16.39	10.4	9.615	14.7	6.803
1.9	52.63	6.2	16.13	10.5	9.524	14.8	6.757
2.0	50.00	6.3	15.87	10.6	9.434	14.9	6.711
2.1	47.62	6.4	15.63	10.7	9.346	15.0	6.667
2.2	45.45	6.5	15.38	10.8	9.259	15.1	6.623
2.3	43.48	6.6	15.15	10.9	9.174	15.2	6.579
2.4	41.67	6.7	14.93	11.0	9.091	15.3	6.536
2.5	40.00	6.8	14.71	11.1	9.009	15.4	6.494
2.6	38.46	6.9	14.49	11.2	8.929	15.5	6.452
2.7	37.04	7.0	14.29	11.3	8.850	15.6	6.410
2.8	35.71	7.1	14.08	11.4	8.772	15.7	6.369
2.9	34.48	7.2	13.89	11.5	8.696	15.8	6.329
3.0	33.33	7.3	13.70	11.6	8.621	15.9	6.289
3.1	32.26	7.4	13.51	11.7	8.547	16.0	6.250
3.2	31.25	7.5	13.33	11.8	8.475	16.1	6.211
3.3	30.30	7.6	13.16	11.9	8.403	16.2	6.173
3.4	29.41	7.7	12.99	12.0	8.333	16.3	6.135
3.5	28.57	7.8	12.82	12.1	8.264	16.4	6.098
3.6	27.78	7.9	12.66	12.2	8.197	16.5	6.061
3.7	27.03	8.0	12.50	12.3	8.130	16.6	6.024
3.8	26.32	8.1	12.35	12.4	8.065	16.7	5.988
3.9	25.64	8.2	12.20	12.5	8.000	16.8	5.952
4.0	25.00	8.3	12.05	12.6	7.937	16.9	5.917
4.1	24.39	8.4	11.90	12.7	7.874	17.0	5.882
4.2	23.81	8.5	11.76	12.8	7.813	17.1	5.848
4.3	23.26	8.6	11.63	12.9	7.752	17.2	5.814

TABLE.—(*Continued*)

Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required
17.3	5.780	22.0	4.545	26.7	3.745	31.4	3.185
17.4	5.747	22.1	4.525	26.8	3.731	31.5	3.175
17.5	5.714	22.2	4.505	26.9	3.717	31.6	3.165
17.6	5.682	22.3	4.484	27.0	3.704	31.7	3.155
17.7	5.650	22.4	4.464	27.1	3.690	31.8	3.145
17.8	5.618	22.5	4.444	27.2	3.676	31.9	2.135
17.9	5.587	22.6	4.425	27.3	3.663	32.0	3.125
18.0	5.556	22.7	4.405	27.4	3.650	32.1	3.115
18.1	5.525	22.8	4.386	27.5	3.636	32.2	3.106
18.2	5.495	22.9	4.367	27.6	3.623	32.3	3.096
18.3	5.464	23.0	4.348	27.7	3.610	32.4	3.086
18.4	5.435	23.1	4.329	27.8	3.597	32.5	3.077
18.5	5.405	23.2	4.310	27.9	3.584	32.6	3.067
18.6	5.376	23.3	4.292	28.0	3.571	32.7	3.058
18.7	5.348	23.4	4.274	28.1	3.559	32.8	3.049
18.8	5.319	23.5	4.255	28.2	3.546	32.9	3.040
18.9	5.291	23.6	4.237	28.3	3.534	33.0	3.030
19.0	5.263	23.7	4.219	28.4	3.521	33.1	3.021
19.1	5.236	23.8	4.202	28.5	3.509	33.2	3.012
19.2	5.208	23.9	4.184	28.6	3.497	33.3	3.003
19.3	5.181	24.0	4.167	28.7	3.484	33.4	2.994
19.4	5.155	24.1	4.149	28.8	3.472	33.5	2.985
19.5	5.128	24.2	4.132	28.9	3.460	33.6	2.976
19.6	5.102	24.3	4.115	29.0	3.448	33.7	2.967
19.7	5.076	24.4	4.098	29.1	3.436	33.8	2.959
19.8	5.051	24.5	4.082	29.2	3.425	33.9	2.950
19.9	5.025	24.6	4.065	29.3	3.413	34.0	2.941
20.0	5.000	24.7	4.049	29.4	3.401	34.1	2.933
20.1	4.975	24.8	4.032	29.5	3.390	34.2	2.924
20.2	4.950	24.9	4.016	29.6	3.378	34.3	2.915
20.3	4.926	25.0	4.000	29.7	3.367	34.4	2.907
20.4	4.902	25.1	3.984	29.8	3.356	34.5	2.899
20.5	4.878	25.2	3.968	29.9	3.344	34.6	2.890
20.6	4.854	25.3	3.953	30.0	3.333	34.7	2.882
20.7	4.831	25.4	3.937	30.1	3.322	34.8	2.874
20.8	4.808	25.5	3.922	30.2	3.311	34.9	2.865
20.9	4.785	25.6	3.906	30.3	3.300	35.0	2.857
21.0	4.762	25.7	3.891	30.4	3.289	35.1	2.849
21.1	4.739	25.8	3.876	30.5	3.279	35.2	2.841
21.2	4.717	25.9	3.861	30.6	3.268	35.3	2.833
21.3	4.695	26.0	3.846	30.7	3.257	35.4	2.825
21.4	4.673	26.1	3.831	30.8	3.247	35.5	2.817
21.5	4.651	26.2	3.817	30.9	3.236	35.6	2.809
21.6	4.630	26.3	3.802	31.0	3.226	35.7	2.801
21.7	4.608	26.4	3.788	31.1	3.215	35.8	2.793
21.8	4.587	26.5	3.774	31.2	3.205	35.9	2.786
21.9	4.566	26.6	3.759	31.3	3.195	36.0	2.778

TABLE. – (*Continued*)

Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required
36.1	2.770	40.8	2.451	45.5	2.198	50.2	1.992
36.2	2.762	40.9	2.445	45.6	2.193	50.3	1.988
36.3	2.755	41.0	2.439	45.7	2.188	50.4	1.984
36.4	2.747	41.1	2.433	45.8	2.183	50.5	1.980
36.5	2.740	41.2	2.427	45.9	2.179	50.6	1.976
36.6	2.732	41.3	2.421	46.0	2.174	50.7	1.972
36.7	2.725	41.4	2.415	46.1	2.169	50.8	1.969
36.8	2.717	41.5	2.410	46.2	2.165	50.9	1.965
36.9	2 710	41.6	2.404	46.3	2.160	51.0	1.961
37.0	2.703	41.7	2.398	46.4	2.155	51.1	1.957
37.1	2.695	41.8	2.392	46.5	2.151	51.2	1.953
37.2	2.688	41.9	2.387	46.6	2.146	51.3	1.949
37.3	2.681	42.0	2.381	46.7	2.141	51.4	1.946
37.4	2.674	42.1	2.375	46.8	2.137	51.5	1.942
37.5	2.667	42.2	2.370	46.9	2.132	51.6	1.938
37.6	2.660	42.3	2.364	47.0	2.128	51.7	1.934
37.7	2.653	42.4	2.358	47.1	2.123	51.8	1.931
37.8	2.646	42.5	2.353	47.2	2.119	51.9	1.927
37.9	2.639	42.6	2.347	47.3	2.114	52.0	1.923
38.0	2.632	42.7	2.342	47.4	2.110	52.1	1.919
38.1	2.625	42.8	2.336	47.5	2.105	52.2	1.916
38.2	2.618	42.9	2.331	47.6	2.101	52.3	1.912
38.3	2.611	43.0	2.326	47.7	2.096	52.4	1.908
38.4	2.604	43.1	2.320	47.8	2.092	52.5	1.905
38.5	2.597	43.2	2.315	47.9	2.088	52.6	1.901
38.6	2.591	43.3	2.309	48.0	2.083	52.7	1.898
38.7	2.584	43.4	2.304	48.1	2.079	52.8	1.894
38.8	2.577	43.5	2.299	48.2	2.075	52.9	1.890
38.9	2.571	43.6	2.294	48.3	2.070	53.0	1.887
39.0	2.564	43.7	2.288	48.4	2.066	53.1	1.883
39.1	2.558	43.8	2.283	48.5	2.062	53.2	1.880
39.2	2.551	43.9	2.278	48.6	2.058	53.3	1.876
39.3	2.545	44.0	2.273	48.7	2.053	53.4	1.873
39.4	2.538	44.1	2.268	48.8	2.049	53.5	1.869
39.5	2.532	44.2	2.262	48.9	2.045	53.6	1.866
39.6	2.525	44.3	2.257	49.0	2.041	53.7	1.862
39.7	2.519	44.4	2.252	49.1	2.037	53.8	1.859
39.8	2.513	44.5	2.247	49.2	2.033	53.9	1.855
39.9	2.506	44.6	2.242	49.3	2.028	54.0	1.852
40.0	2.500	44.7	2.237	49.4	2.024	54.1	1.848
40.1	2.494	44.8	2.232	49.5	2.020	54.2	1.845
40.2	2.488	44.9	2.227	49.6	2.016	54.3	1.842
40.3	2.481	45.0	2.222	49.7	2.012	54.4	1.838
40.4	2.475	45.1	2.217	49.8	2.008	54.5	1.835
40.5	2.469	45.2	2.212	49.9	2.004	54.6	1.832
40.6	2.463	45.3	2.208	50.0	2.000	54.7	1.828
40.7	2 457	45.4	2.203	50.1	1.996	54.8	1.825

TABLE.—(*Continued*)

Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required
54.9	1.821	59.6	1.678	64.3	1.555	69.0	1.449
55.0	1.818	59.7	1.675	64.4	1.553	69.1	1.447
55.1	1.815	59.8	1.672	64.5	1.550	69.2	1.445
55.2	1.812	59.9	1.669	64.6	1.548	69.3	1.443
55.3	1.808	60.0	1.667	64.7	1.546	69.4	1.441
55.4	1.805	60.1	1.664	64.8	1.543	69.5	1.439
55.5	1.802	60.2	1.661	64.9	1.541	69.6	1.437
55.6	1.799	60.3	1.658	65.0	1.538	69.7	1.435
55.7	1.795	60.4	1.656	65.1	1.536	69.8	1.433
55.8	1.792	60.5	1.653	65.2	1.534	69.9	1.431
55.9	1.789	60.6	1.650	65.3	1.531	70.0	1.429
56.0	1.786	60.7	1.647	65.4	1.529	70.1	1.427
56.1	1.783	60.8	1.645	65.5	1.527	70.2	1.425
56.2	1.779	60.9	1.642	65.6	1.524	70.3	1.422
56.3	1.776	61.0	1.639	65.7	1.522	70.4	1.420
56.4	1.773	61.1	1.637	65.8	1.520	70.5	1.418
56.5	1.770	61.2	1.634	65.9	1.517	70.6	1.416
56.6	1.767	61.3	1.631	66.0	1.515	70.7	1.414
56.7	1.764	61.4	1.629	66.1	1.513	70.8	1.412
56.8	1.761	61.5	1.626	66.2	1.511	70.9	1.410
56.9	1.757	61.6	1.623	66.3	1.508	71.0	1.408
57.0	1.754	61.7	1.621	66.4	1.506	71.1	1.406
57.1	1.751	61.8	1.618	66.5	1.504	71.2	1.404
57.2	1.748	61.9	1.616	66.6	1.502	71.3	1.403
57.3	1.745	62.0	1.613	66.7	1.499	71.4	1.401
57.4	1.742	62.1	1.610	66.8	1.497	71.5	1.399
57.5	1.739	62.2	1.608	66.9	1.495	71.6	1.397
57.6	1.736	62.3	1.605	67.0	1.493	71.7	1.395
57.7	1.733	62.4	1.603	67.1	1.490	71.8	1.393
57.8	1.730	62.5	1.600	67.2	1.488	71.9	1.391
57.9	1.727	62.6	1.597	67.3	1.486	72.0	1.389
58.0	1.724	62.7	1.595	67.4	1.484	72.1	1.387
58.1	1.721	62.8	1.592	67.5	1.481	72.2	1.385
58.2	1.718	62.9	1.590	67.6	1.479	72.3	1.383
58.3	1.715	63.0	1.587	67.7	1.477	72.4	1.381
58.4	1.712	63.1	1.585	67.8	1.475	72.5	1.379
58.5	1.709	63.2	1.582	67.9	1.473	72.6	1.377
58.6	1.706	63.3	1.580	68.0	1.471	72.7	1.376
58.7	1.704	63.4	1.577	68.1	1.468	72.8	1.374
58.8	1.701	63.5	1.575	68.2	1.466	72.9	1.372
58.9	1.698	63.6	1.572	68.3	1.464	73.0	1.370
59.0	1.695	63.7	1.570	68.4	1.462	73.1	1.368
59.1	1.692	63.8	1.567	68.5	1.460	73.2	1.366
59.2	1.689	63.9	1.565	68.6	1.458	73.3	1.364
59.3	1.686	64.0	1.563	68.7	1.456	73.4	1.362
59.4	1.684	64.1	1.560	68.8	1.453	73.5	1.361
59.5	1.681	64.2	1.558	68.9	1.451	73.6	1.359

TABLE.—(*Continued*)

Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required
73.7	1.357	78.4	1.276	83.1	1.203	87.8	1.139
73.8	1.355	78.5	1.274	83.2	1.202	87.9	1.138
73.9	1.353	78.6	1.272	83.3	1.200	88.0	1.136
74.0	1.351	78.7	1.271	83.4	1.199	88.1	1.135
74.1	1.350	78.8	1.269	83.5	1.198	88.2	1.134
74.2	1.348	78.9	1.267	83.6	1.196	88.3	1.133
74.3	1.346	79.0	1.266	83.7	1.195	88.4	1.131
74.4	1.344	79.1	1.264	83.8	1.193	88.5	1.130
74.5	1.342	79.2	1.263	83.9	1.192	88.6	1.129
74.6	1.340	79.3	1.261	84.0	1.190	88.7	1.127
74.7	1.339	79.4	1.259	84.1	1.189	88.8	1.126
74.8	1.337	79.5	1.258	84.2	1.188	88.9	1.125
74.9	1.335	79.6	1.256	84.3	1.186	89.0	1.124
75.0	1.333	79.7	1.255	84.4	1.185	89.1	1.122
75.1	1.332	79.8	1.253	84.5	1.183	89.2	1.121
75.2	1.330	79.9	1.252	84.6	1.182	89.3	1.120
75.3	1.328	80.0	1.250	84.7	1.181	89.4	1.119
75.4	1.326	80.1	1.248	84.8	1.179	89.5	1.117
75.5	1.325	80.2	1.247	84.9	1.178	89.6	1.116
75.6	1.323	80.3	1.245	85.0	1.176	89.7	1.115
75.7	1.321	80.4	1.244	85.1	1.175	89.8	1.114
75.8	1.319	80.5	1.242	85.2	1.174	89.9	1.112
75.9	1.318	80.6	1.241	85.3	1.172	90.0	1.111
76.0	1.316	80.7	1.239	85.4	1.171	90.1	1.110
76.1	1.314	80.8	1.238	85.5	1.170	90.2	1.109
76.2	1.312	80.9	1.236	85.6	1.168	90.3	1.107
76.3	1.311	81.0	1.235	85.7	1.167	90.4	1.106
76.4	1.309	81.1	1.233	85.8	1.166	90.5	1.105
76.5	1.307	81.2	1.232	85.9	1.164	90.6	1.104
76.6	1.305	81.3	1.230	86.0	1.163	90.7	1.103
76.7	1.304	81.4	1.229	86.1	1.161	90.8	1.101
76.8	1.302	81.5	1.227	86.2	1.160	90.9	1.100
76.9	1.300	81.6	1.225	86.3	1.159	91.0	1.099
77.0	1.299	81.7	1.224	86.4	1.157	91.1	1.098
77.1	1.297	81.8	1.222	86.5	1.156	91.2	1.096
77.2	1.295	81.9	1.221	86.6	1.155	91.3	1.095
77.3	1.294	82.0	1.220	86.7	1.153	91.4	1.094
77.4	1.292	82.1	1.218	86.8	1.152	91.5	1.093
77.5	1.290	82.2	1.217	86.9	1.151	91.6	1.092
77.6	1.289	82.3	1.215	87.0	1.149	91.7	1.091
77.7	1.287	82.4	1.214	87.1	1.148	91.8	1.089
77.8	1.285	82.5	1.212	87.2	1.147	91.9	1.088
77.9	1.284	82.6	1.211	87.3	1.145	92.0	1.087
78.0	1.282	82.7	1.209	87.4	1.144	92.1	1.086
78.1	1.280	82.8	1.208	87.5	1.143	92.2	1.085
78.2	1.279	82.9	1.206	87.6	1.142	92.3	1.083
78.3	1.277	83.0	1.205	87.7	1.140	92.4	1.082

TABLE.—(*Concluded*)

Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required	Percentage present	Pounds required
92.5	1.081	94.4	1.059	96.3	1.038	98.2	1.018
92.6	1.080	94.5	1.058	96.4	1.037	98.3	1.017
92.7	1.079	94.6	1.057	96.5	1.036	98.4	1.016
92.8	1.078	94.7	1.056	96.6	1.035	98.5	1.015
92.9	1.076	94.8	1.055	96.7	1.034	98.6	1.014
93.0	1.075	94.9	1.054	96.8	1.033	98.7	1.013
93.1	1.074	95.0	1.053	96.9	1.032	98.8	1.012
93.2	1.073	95.1	1.052	97.0	1.031	98.9	1.011
93.3	1.072	95.2	1.050	97.1	1.030	99.0	1.010
93.4	1.071	95.3	1.049	97.2	1.029	99.1	1.009
93.5	1.070	95.4	1.048	97.3	1.028	99.2	1.008
93.6	1.068	95.5	1.047	97.4	1.027	99.3	1.007
93.7	1.067	95.6	1.046	97.5	1.026	99.4	1.006
93.8	1.066	95.7	1.045	97.6	1.025	99.5	1.005
93.9	1.065	95.8	1.044	97.7	1.024	99.6	1.004
94.0	1.064	95.9	1.043	97.8	1.022	99.7	1.003
94.1	1.063	96.0	1.042	97.9	1.021	99.8	1.002
94.2	1.062	96.1	1.041	98.0	1.020	99.9	1.001
94.3	1.060	96.2	1.040	98.1	1.019	100.0	1.000

APPENDIX.

THE AGRICULTURAL EXPERIMENT STATIONS.

ALABAMA—
College Station: *Auburn.*
Canebrake Station: *Uniontown.*
Tuskegee Station: *Tuskegee Institute.*
ALASKA—*Sitka.*
ARIZONA—*Tucson.*
ARKANSAS—*Fayetteville.*
CALIFORNIA—*Berkeley.*
COLORADA—*Fort Collins.*
CONNECTICUT—
State Station: *New Haven.*
Storrs Station: *Storrs.*
DELAWARE—*Newark.*
FLORIDA—*Gainesville.*
GEORGIA—*Experiment.*
GUAM—*Island of Guam.*
HAWAII—
Federal Station: *Honolulu.*
Sugar Planters' Station: *Honolulu.*
IDAHO—*Moscow.*
ILLINOIS—*Urbana.*
INDIANA—*Lafayette.*
IOWA—*Ames.*
KANSAS—*Manhattan.*
KENTUCKY—*Lexington.*
LOUISIANA—
State Station: *Baton Rouge.*
Sugar Station: *Audubon Park, New Orleans.*
North Louisiana Station: *Calhoun.*
Rice Experiment Station: *Crowley.*
MAINE—*Orono.*
MARYLAND—*College Park.*
MASSACHUSETTS—*Amherst.*
MICHIGAN—*East Lansing.*
MINNESOTA—*University Farm, St. Paul.*
MISSISSIPPI—*Agricultural College.*
MISSOURI—
College Station: *Columbia.*
Fruit Station: *Mountain Grove.*
MONTANA—*Bozeman.*
NEBRASKA—*Lincoln.*
NEVADA—*Reno.*
NEW HAMPSHIRE—*Durham.*
NEW JERSEY—*New Brunswick.*
NEW MEXICO—*Agricultural College.*
NEW YORK—
State Station: *Geneva.*
Cornell Station: *Ithaca.*
NORTH CAROLINA—
College Station: *West Raleigh.*
State Station: *Raleigh.*
NORTH DAKOTA—*Agricultural College.*
OHIO—*Wooster.*
OKLAHOMA—*Stillwater.*
OREGON—*Corvallis.*
PENNSYLVANIA—
State College.
State College: Institute of Animal Nutrition.
PORTO RICO—*Mayaguez.*
RHODE ISLAND—*Kingston.*
SOUTH CAROLINA—*Clemson College.*
SOUTH DAKOTA—*Brookings.*
TENNESSEE—*Knoxville.*
TEXAS—*College Station.*
UTAH—*Logan.*
VERMONT—*Burlington.*
VIRGINIA—
Blacksburg.
Norfolk: Truck Station.
WASHINGTON—*Pullman.*
WEST VIRGINIA—*Morgantown.*
WISCONSIN—*Madison.*
WYOMING—*Laramie.*

How to Collect an Exhibit of Fertilizer Materials.

If the teacher wishes to make this subject more interesting an elaborate exhibit of the different fertilizer materials and mixed fertilizers should be secured. The mixed fertilizers may be obtained on the local market during late winter or early spring, or perhaps from your state chemist. For special materials you may be able to obtain them from the following addresses. When you write for any of these materials, state that you wish to use them in class work. The farmer or consumer cannot expect to receive a collection of these materials.

Stassfurt potash salts, German Kali Works, 93 Nassau St., New York City.

Nitrate of soda, Nitrate Agencies Co., 64 Stone St., New York City.

Calcium cyanamid, American Calcium Cyanamid Co., Baltimore, Md.

Sulphate of ammonia, American Coal Products Co., New York City.

Cotton-seed meal, American Cotton Oil Co., New York City.

Linseed meal, American Linseed Co., Chicago, Ill.

Acid phosphate, from any Fertilizer Co.

Rock phosphate, (Florida land pebble), The Phosphate Mining Co., 92 Williams St., New York City.

Rock phosphate, (Florida hard rock), Camp Phosphate Co., Ocala, Florida.

Rock phosphate, (Tennessee), Tennessee Blue Rock Phosphate Co., Mt. Pleasant, Tenn.

Rock phosphate, (Tennessee), Williams Phosphate Co., Mt. Pleasant, Tenn.

Basic slag and Peruvian Guano, Coe-Mortimer Co., New York City.

Tankage and Bone Products, Swift and Co., or Armour and Co., Chicago, Ill.

Blood, Armour and Co., Chicago, Ill.

Azotin, J. B. Sardy, Chicago, Ill.

Bone-black, American Agricultural Chemical Co., New York City.

Carbonate of potash, Peters, White and Co., New York City.

Concentrated superphosphate, Virginia-Carolina, Chemical Co., Richmond, Va.

Concentrated tankage, Heller, Hirsh & Co., New York City.

Dried fish scrap, White & Co., Baltimore, Md.

Garbage tankage, Heller, Hirsh & Co., New York City.

Ground tobacco stems and dust, Kentucky Tobacco Product Co., Louisville, Ky.

Hair, all kinds, White and Co., Baltimore, Md.

Hoof meal and peat, J. B. Sardy, Chicago, Ill.

Pyrites, Naylor & Co., New York City.

Potassium nitrate; obtain this in a general store, or at a drug store.

Whale guano, Hollingshurst & Co., New York City.

Foreign imported materials, H. J. Baker & Bro., William St., New York City, or, E. J. Walter Co., Baltimore, Md.

It must be understood that there are several parties who handle fertilizer materials and if you are unable to secure what you desire by writing to the one mentioned here, kindly ask the concern you write, to furnish you with some addresses of people who are liable to have the desired material or materials in stock.

The following table, the work of American and foreign investigators will acquaint the student with the fertilizer constituents in feed stuffs:

FERTILIZING CONSTITUENTS IN AMERICAN FEED STUFFS

Name of feed	Water per cent.	Ash per cent	Nitrogen per cent	Phosphoric acid per cent.	Potassium oxide per cent.
CONCENTRATES					
Barley	14.30	2.48	1.51	0.79	0.48
Beet pulp (dried)	8.00	5.40	1.60	0.16	1.47
Brewers' grains (dried)	6.98	6.15	3.05	1.26	1.55
Brewers' grains (wet)	75.01	1.00	0.89	0.31	0.05
Broom corn seed	14.10	3.40	1.63	——	——
Buckwheat	14.10	2.00	1.44	0.44	0.21
Buckwheat middlings	14.70	1.40	1.38	0.68	0.34
Corn (grain)	10.88	1.53	1.82	0.70	0.40
Corn bran	9.10	1.30	1.63	1.21	0.68
Corn and cob meal	8.96	1.50	1.41	0.57	0.47
Cotton-seed (raw)	10.30	3.50	3.13	1.27	1.17
Cotton-seed meal	9.90	6.82	6.64	2.68	1.79
Cowpea seed	14.80	3.20	3.33	——	——
Distillers' dried grains	8.00	1.70	4.50	0.61	0.31
Flax-seed	9.20	4.20	3.61	1.39	1.03
Flour (dark feeding)	9.70	4.30	3.18	2.14	1.09
Flour (high grade)	12.20	0.60	1.89	0.22	0.15
Flour (low grade)	12.00	2.00	2.89	0.56	0.35
Germ meal	8.10	1.30	2.65	0.80	0.50
Gluten meal	8.59	0.73	5.03	0.33	0.05
Gluten feed	8.50	1.70	3.84	0.41	0.03
Grano-gluten	5.80	2.80	4.98	0.51	0.15
Hominy chops	11.10	2.50	1.63	0.98	0.49
Hominy meal	11.00	2.50	1.66	1.25	0.78
Horse bean	11.30	3.80	4.07	1.20	1.29
Linseed meal (old process)	8.88	6.08	5.43	1.66	1.37
Linseed meal (new process)	7.77	5.37	5.78	1.83	1.39
Malt sprouts	10.38	5.72	3.55	1.43	1.63
Millet seed	14.00	3.30	2.04	0.85	0.36
Molasses (beet)	20.80	10.60	1.46	0.05	5.63
Molasses (cane, blackstrap)	22.40	9.30	0.47	0.14	3.70
Oats	11.00	3.00	2.06	0.82	0.62
Oat dust	6.50	6.90	2.16	——	——
Oat feed (shorts)	7.70	3.70	1.72	0.91	0.53
Oat meal	7.90	2.00	2.35	——	——
Peanut meal	10.70	4.90	7.56	1.31	1.50
Peas	10.50	2.60	3.08	0.82	0.99
Rape-seed meal	10.00	7.90	4.96	2.00	1.30
Rice (clean)	12.80	0.70	1.08	0.18	0.09
Rice bran (impure)	9.90	13.00	0.71	0.29	0.24
Rice polish	10.30	3.50	1.97	0.30	0.71
Rye	11.60	1.90	1.76	0.82	0.54
Rye bran	11.60	4.60	2.32	2.28	1.40
Rye shorts	9.30	5.90	1.84	1.26	0.81
Soja (soy) bean	10.80	4.70	5.30	1.87	1.99
Sorghum seed	12.80	2.10	1.48	0.81	0.42
Sunflower seed	8.60	2.60	2.28	1.22	0.56
Sunflower seed cake	10.80	6.70	5.55	2.15	1.17

FERTILIZING CONSTITUENTS IN AMERICAN FEED STUFFS.—(*Continued*)

Name of feed	Water per cent.	Ash per cent.	Nitrogen per cent.	Phosphoric acid per cent.	Potassium oxide per cent.
CONCENTRATES—(Continued)					
Wheat (grain)	10.50	1.80	2.36	0.79	0.50
Wheat bran	11.90	6.30	2.67	2.89	1.61
Wheat middlings	12.10	3.30	2.63	0.95	0.63
Wheat screenings	11.60	2.90	2.44	1.17	0.84
Wheat shorts	11.80	4.60	2.82	1.35	0.59
WASTE PRODUCTS (low grade)					
Buckwheat hulls	13.20	2.20	0.49	0.07	0.52
Corn cob	10.70	1.40	0.50	0.06	0.60
Cotton-seed hulls	11.10	2.80	0.69	0.25	1.02
Oat hulls	7.30	6.60	0.52	0.24	0.52
Rice hulls	9.00	18.30	0.58	0.17	0.14
GREEN FODDERS					
Alfalfa	75.30	2.25	0.72	0.13	0.56
Apple pomace silage	75.00	1.05	0.32	0.15	0.40
Canada field pea	85.00	1.20	0.50	0.12	0.38
Clover (alsike)	81.80	1.47	0.44	0.11	0.20
Clover (red)	80.00	1.45	0.53	0.13	0.46
Clover (scarlet)	82.50	1.42	0.43	0.13	0.49
Clover (white)	81.00	——	0.56	0.20	0 24
Corn silage	79.10	1.40	0.28	0.11	0 37
Corn and soy bean silage	76.00	2.40	0.79	0.42	0.44
Cowpea	78.81	1.47	0.27	0.10	0.31
Flat pea	71.60	1.93	1.13	0.18	0.58
Horse bean	84.20	——	0.68	0.33	1.37
Italian rye grass	74.85	2.84	0.54	0.29	1.14
Lupine (white)	85.35	——	0.44	0.35	1.73
Lupine (yellow)	83.15	0.96	0.51	0.11	0.15
Millet (common)	62.58	1.20	0.61	0.19	0.41
Millet (Hungarian grass)	71 10	1.70	0.39	0.16	0.55
Millet (Japanese)	80.00	1.10	0.53	0.20	0.34
Millet (silage)	74.00	——	0.26	0.14	0.62
Millet and soy bean silage.	79.00	2.80	0.42	0.11	0.44
Oat fodder	83.36	1.31	0.49	0.13	0.38
Oats and vetch (1-1)	80.00	1.80	0.43	0.14	0.30
Orchard grass	73.14	2.09	0.43	0.16	0.76
Pasture grasses (mixed)	63.12	3.27	0.91	0.23	0.75
Perennial rye grass	75.20	2.60	0.47	0.28	1.10
Prickly comfrey	84.36	2.45	0.42	0.11	0.75
Rape	85.00	——	0.34	0.10	0.78
Rye fodder	76.60	2.10	0.33	0.15	0.73
Serradella	82.59	1.82	0.41	0.14	0.42
Soja (soy) bean	75.10	2.60	0.29	0.15	0.53
Sorghum fodder	79.40	1.10	0.23	0.09	0.23
Timothy	66.90	2.15	0.48	0.26	0.76
Vetch (common)	84.50	1.94	0.59	1.19	0.70
HAY AND DRY COARSE FODDERS					
Alfalfa	8.40	7.40	2.19	0.51	1.68

FERTILIZING CONSTITUENTS IN AMERICAN FEED STUFFS.—(*Continued*)

Name of feed	Water per cent.	Ash per cent.	Nitrogen per cent.	Phosphoric acid per cent.	Potassium oxide per cent.
HAY AND DRY COARSE FODDERS—(Continued)					
Branch grass	16.00	——	1.06	0.19	0.87
Broom corn stalks (waste)	10.00	——	0.87	0.47	1.87
Blue melilot	8.22	13.65	1.92	0.54	2.80
Carrot tops (dry)	9.76	12.52	3.13	0.61	4.88
Clover (alsike)	9.94	11.11	2.34	0.67	2.23
Clover (Bokhara)	7.43	7.70	1.98	0.56	1.83
Clover (crimson)	9.60	8.60	2.05	0.40	1.31
Clover (mammoth red)	15.00	6.30	2.14	0.52	1.80
Clover (red)	15.00	6.20	2.07	0.48	2.20
Clover (white)	——	——	2.75	0.52	1.81
Corn fodder (with ears)	7.85	4.91	1.76	0.54	0.89
Corn fodder (without ears)	9.12	3.74	1.04	0.29	1.40
English hay (mixed grasses)	14.00	5.30	1.34	0.32	1.61
Fox grass	16.00	——	1.18	0.18	0.95
Italian rye grass	8.71	6.40	1.19	0.56	1.27
Japanese buckwheat	5.72	——	1.63	0.85	3.32
Kentucky blue grass	10.35	4.16	1.19	0.40	1.57
Meadow fescue grass	8.89	8.08	0.99	0.40	2.10
Meadow foxtail	15.35	5.24	1.54	0.44	1.99
Millet (common)	9.75	——	1.28	0.49	1.69
Millet (Hungarian grass)	7.69	6.18	1.20	0.35	1.30
Millet (Japanese)	10.45	5.80	1.11	0.40	1.22
Mixed grasses	11.99	6.34	1.41	0.27	1.55
Oat fodder	15.00	5.20	1.90	0.65	1.90
Orchard grass	8.84	6.42	1.31	0.41	1.88
Oxeye daisy	9.65	6.37	0 28	0.44	1.25
Perennial rye grass	9.13	6.79	1.23	0.56	1.55
Red top	7.71	4.59	1.15	0.36	1.02
Rowen (mixed)	16.60	6.80	1.61	0.43	1.49
Sainfoin	12.17	7.55	2.63	0.76	2.02
Serradella	7.39	10.60	2.70	0.78	0.65
Spanish moss	15.00	1.40	0.61	0.07	0.56
Soy bean (whole plant)	11.30	7.20	2.32	0.67	1.08
Sulla	9.39	——	2.46	0.45	2.09
Tall meadow oat grass	15.35	4.92	1.16	0 32	1.72
Teosinte	6.06	6.53	1.46	0.55	3.70
Timothy	13.20	4.40	1.26	0.53	0.90
Vetch and oats (1–1)	15.00	7.40	1.80	0.60	1.27
White daisy	10.30	6.60	0.26	0.41	1.18
STRAW					
Barley straw	14.20	5.80	1.31	0.30	2.09
Barley chaff	13.08	——	1.01	0.27	0.99
Millet straw	15.00	——	0.68	0.18	1.73
Oat straw	9.20	5.10	0.62	0.20	1.24
Rye straw	7.10	3.20	0.46	0.28	0.79
Soja bean	10.10	5.80	1.75	0.40	1.32

FERTILIZING CONSTITUENTS IN AMERICAN FEED STUFFS.—(*Continued*)

Name of feed	Water per cent.	Ash per cent.	Nitrogen per cent.	Phosphoric acid per cent.	Potassium oxide per cent.
STRAW—(Continued)					
Wheat straw	9.60	4.20	0.59	0.12	0.51
Wheat chaff	14.30	9.20	0.79	0.70	0.42
ROOTS, TUBERS, ETC.					
Artichoke	78.00	1.00	0.26	0.14	0.47
Beet (mangel)	90.9	1.10	0.19	0.09	0.38
Beet (red)	88.50	1.00	0.24	0.09	0.44
Beet (sugar)	86.50	0.90	0.22	0.10	0.48
Beet (yellow fodder)	89.00	——	0.23	0.11	0.56
Carrot	88.60	1.20	0.15	0.09	0.51
Mangold	88.00	——	0.15	0.14	0.34
Parsnip	86.30	0.70	0.18	0.20	0.44
Potato (Irish)	78.90	1.00	0.21	0.07	0.29
Radish (Japanese)	93.00	——	0.08	0.05	0.40
Rutabaga	88.60	1.20	0.19	0.12	0.49
Turnip (flat)	90.50	0.80	0.18	0.10	0.39
DAIRY PRODUCTS					
Butter	12.50	——	0.19	——	——
Buttermilk	90.10	0.70	0.48	0.17	0.16
Colostrum (cows' milk)	74.60	1.50	2.82	0.66	0.11
Skim milk (centrifugal)	90.60	0.70	0.56	0.20	0.19
Skim milk (gravity)	90.40	0 70	0.56	0.20	0.19
Whey	93.80	0.40	0.15	0.14	0.18
Whole milk	87.20	0.60	0.53	0.19	0.18
MISCELLANEOUS					
Apples	78.00	——	0.12	0.01	0.17
Cabbage	90.50	1.40	0.38	0.11	0.43
Dried blood	8.50	4.70	13.50	1.35	0.77
Dried fish	10.80	29.20	7.75	12.00	0.20
Meat scrap	10.70	4.10	11.39	0.70	0.10
Pumpkin (garden)	86.80	0.90	0.11	0.16	0.09
Spurry	75.60	4.00	0.38	0.25	0.59
Sugar beet leaves	88.00	2.40	0.41	0.15	0.62

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